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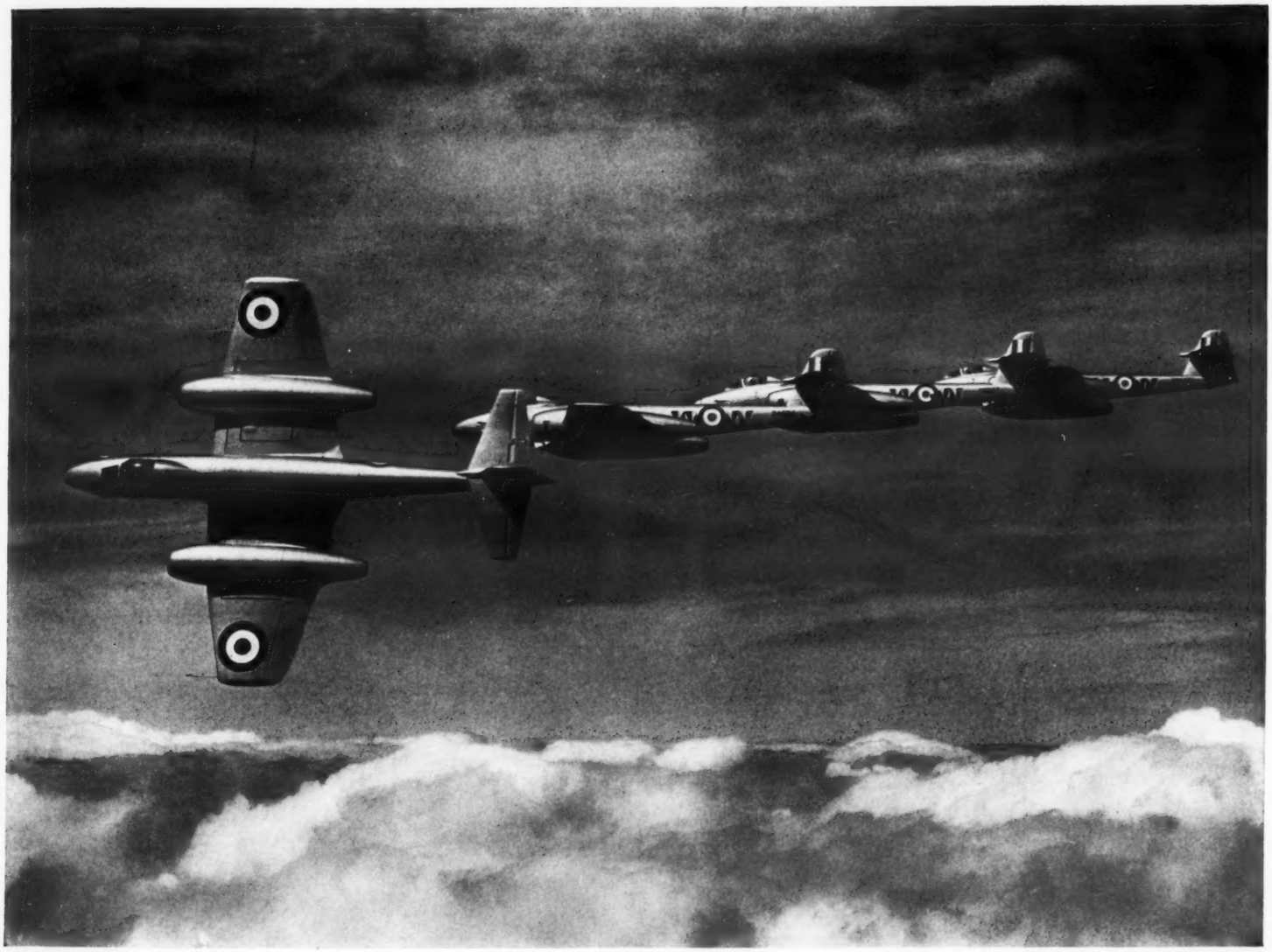

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Faster and Faster . . .

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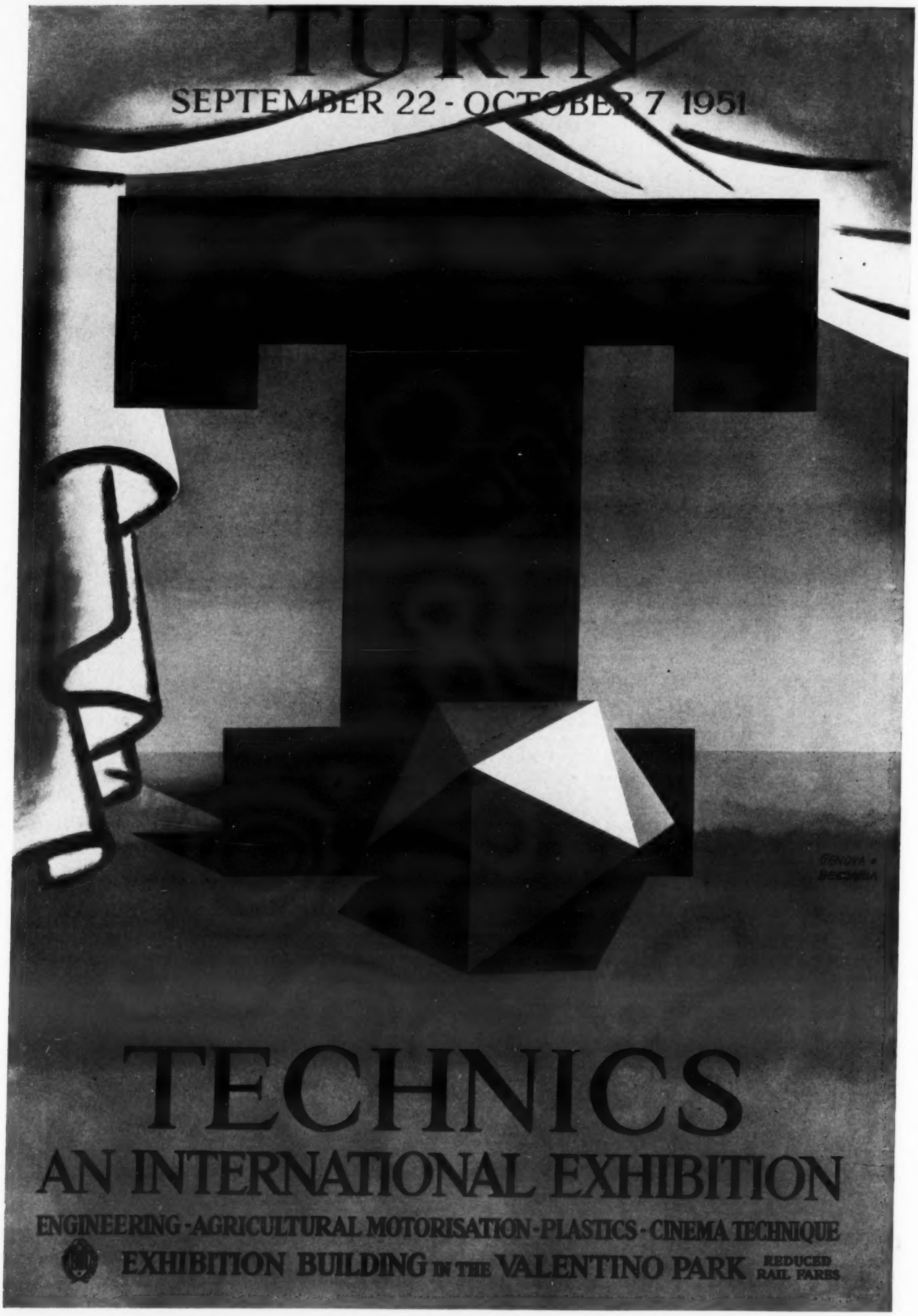
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Review of World Aviation

Volume VI — No 8 — 1951

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Front Cover :

Four Gloster "Meteor 8" fighters of the RAF took part in the high-speed precision acrobatic demonstrations at the Le Bourget Air Display, Paris, on July 1st, 1951.

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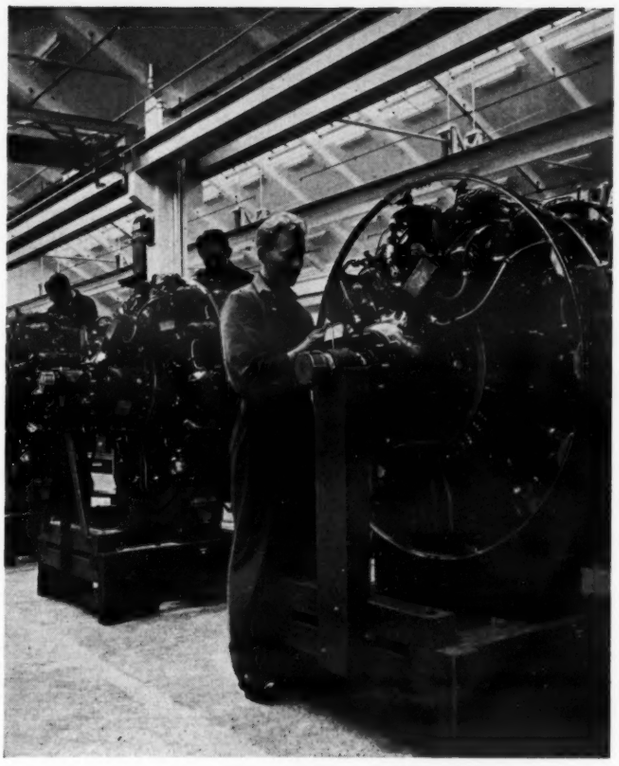

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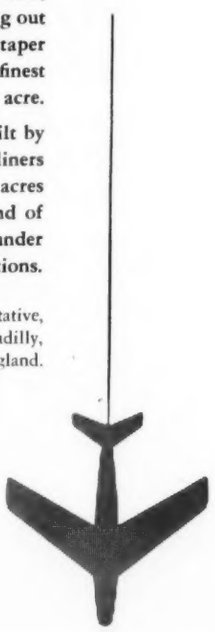

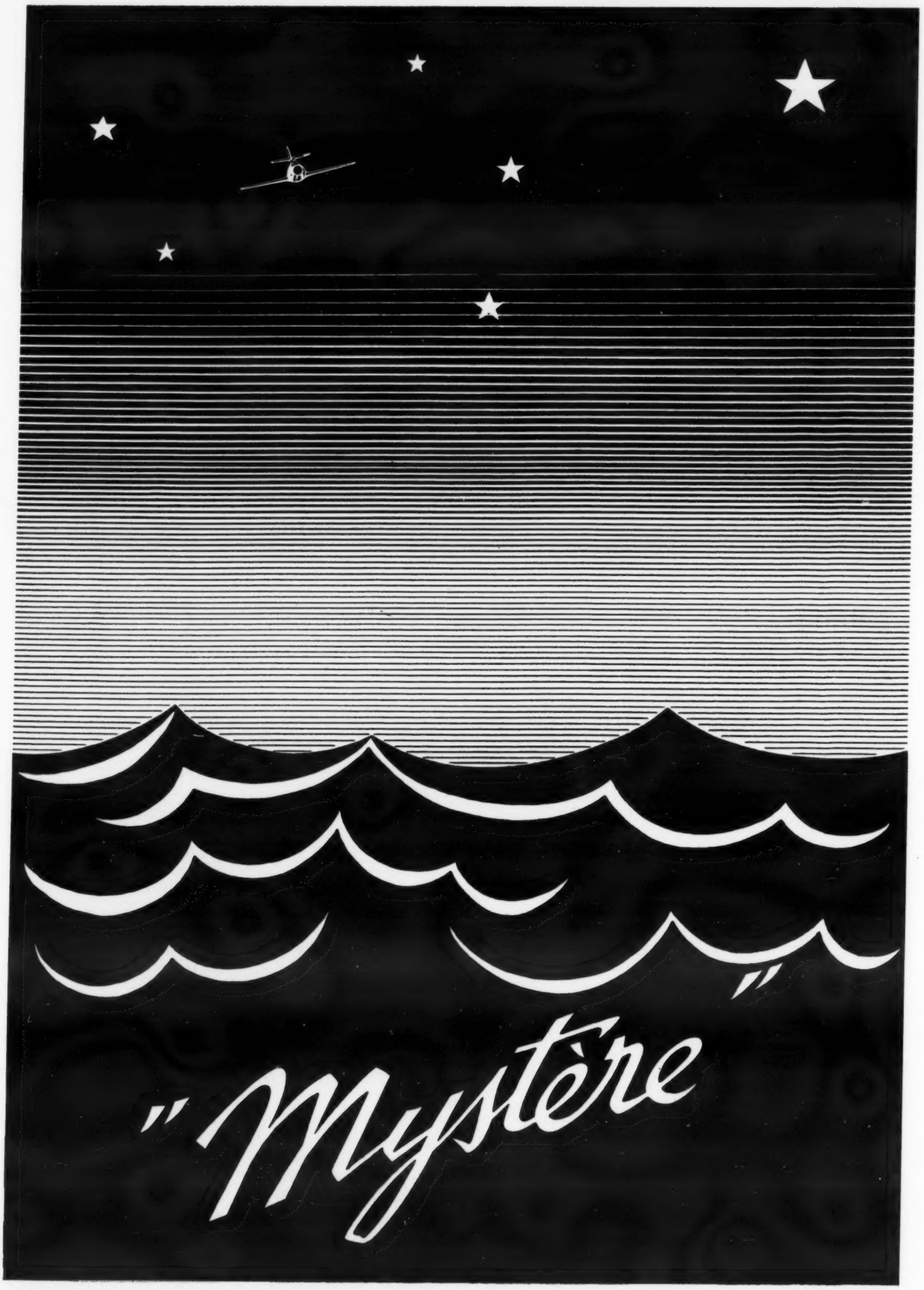
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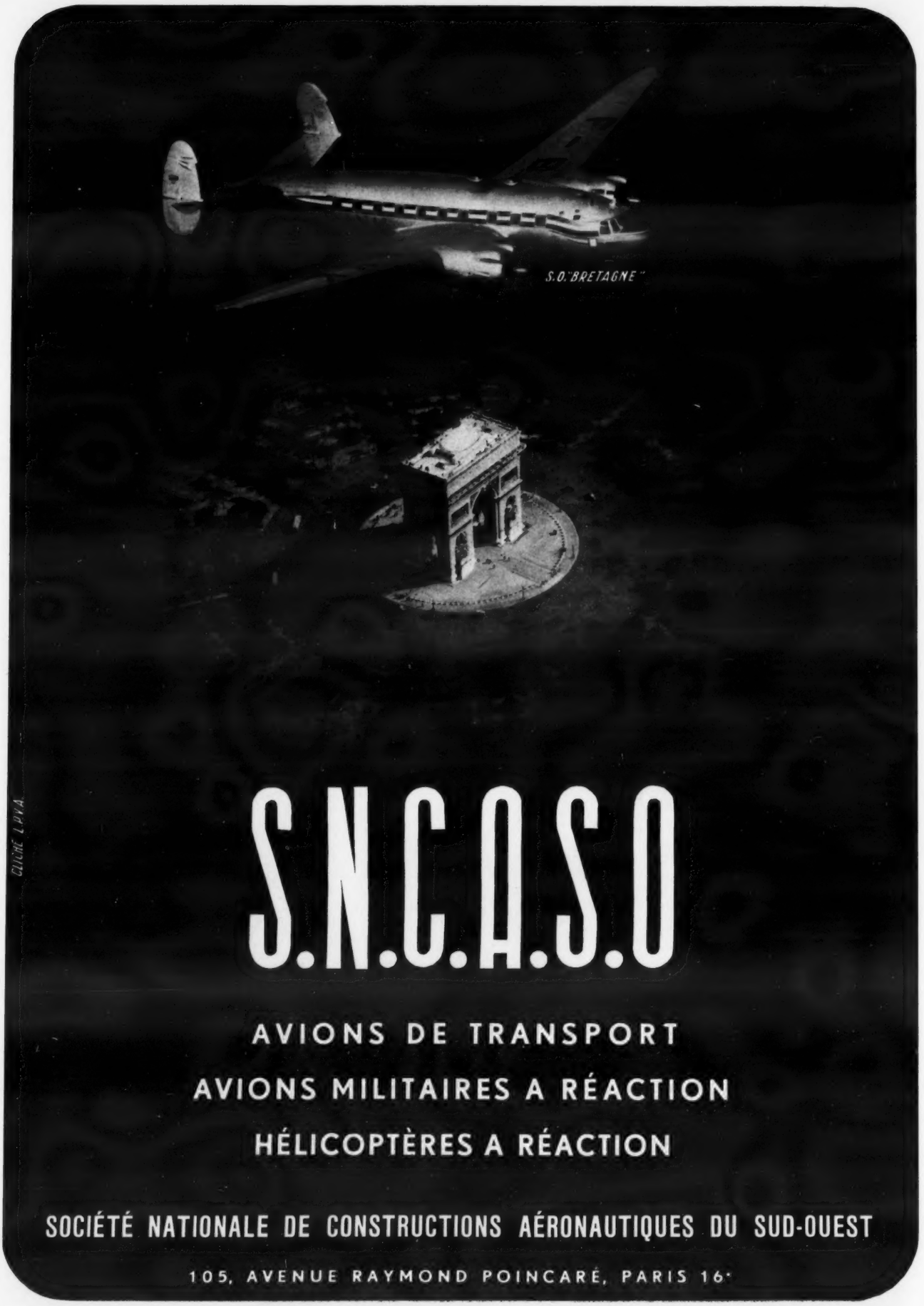

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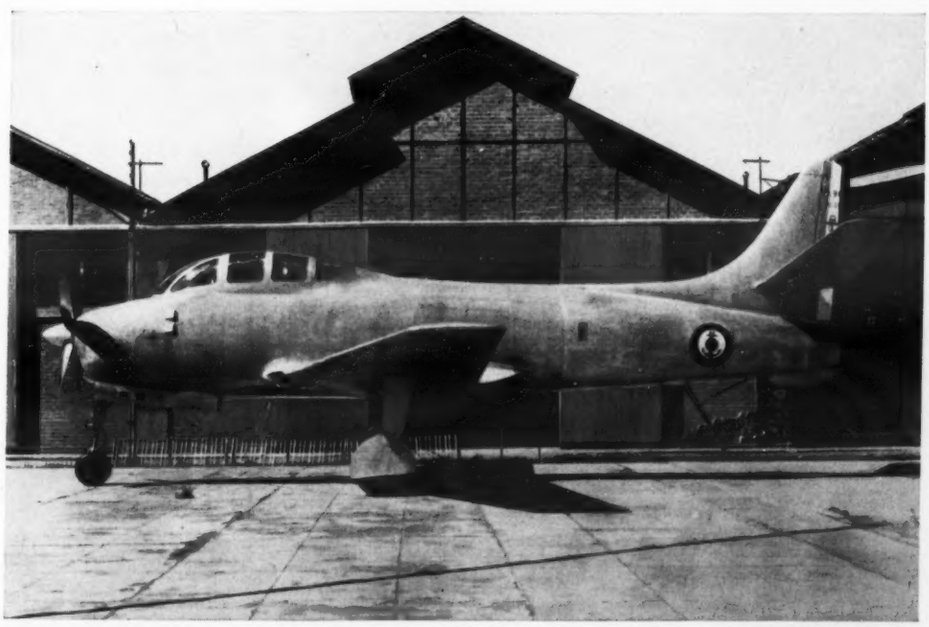

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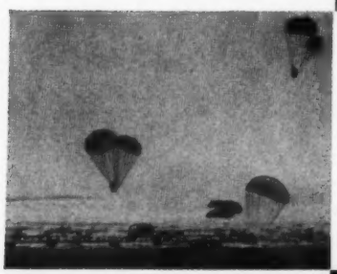

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Speed has the Word

Let us read over again what was written about the 18 th International Aircraft Show two years ago :—*

"Two weeks, and it was over... Granted, some two hundred stands were provided ; by the French, British, Americans, Italians, Dutch, Swiss, and even the Turks. But that certain atmosphere... which characterized previous exhibitions, was absent this time. Why ? ...Why should the man in the street spend his weekend in a building which has somehow never managed to rid itself of the dust from the Paris World Fair of 1900 ? He preferred to visit the countryside or one of the city's sports stadiums. He was aware that modern big airliners cannot be shown in exhibition halls...

Now, the conclusion to this year's Paris Salon was in the shape of two days of aerial demonstrations at Orly Airport. And the visitors made a multitude—laymen and professionals ! They saw British and American types ; they also saw that the French prototypes, which have been like something stored away in the cupboard for another day, were altogether airworthy.

Let us sum up this year's Paris Salon. The French aircraft industry seems to have arisen from its sickbed, and the healing process is progressing satisfactorily..."

Now the 19th Show, which closed its doors on July 1st, 1951, is over in its turn. It was the last that is to be held in the traditional form, as French Defence Minister Jules Moch expressly stated. Once again André Granet, the Show's presiding genius—an organizer of the first rank, but unshakeable in his love for his Grand Palais—was disappointed. Once again Parisians preferred to get out of the town up to the last day, when they flocked in their thousands to Le Bourget airport to watch the flying display.

Once again the French, British, Americans, Italians and Dutch had taken stands. But this time there were not 200 of them in the Grand Palais, indeed not more than 100 at the outside. Whereas in 1949 most of the exhibits were full-size aircraft, this year they were mostly models, helicopters, trainers or—and these formed the *pièce de résistance* of the Show—stands showing electronic and other equipment of outstanding quality. They alone made a visit worthwhile. But is a whole fortnight really necessary for such an exhibition? A week of this "static show" —next time more suitably held at one of the Paris airports—should be enough.

With this single reservation the 1951 Paris Show was the most positive yet presented by international aviation since the war. All the pledges made by the French aircraft industry at earlier Shows have been redeemed. The crowning event was at Le Bourget :— a flying display, organized with split-second precision, for which the Association of the French Aircraft Industry (Union Syndicale des Industries Aéronautiques) and its President, Georges Héreil, were reponsible. There was plenty to convince French and foreign visitors alike that these international displays are not to be missed and should perhaps take place every year. Here Monsieur Granet was able to show how Paris can entertain 2500 guests from all over the world. And the hundreds of thousands of spectators? They, too, certainly got their money's worth.

As Georges Héreil, the Show's President, said in his final speech :—

"A display by the finest aircraft in the world brings the 19th International Air Show to an end today in the sky over Le Bourget... Whereas the 1946 Show was merely the expression of the hopes of an industry which was but starting on the road to recovery from almost complete ruin, the 1949 Salon marked our entry into the realm of facts. This year's Show has proved that we have reached the stage of positive achievement in the execution of a five-year plan. Quantity production is in hand of a number of proven French designs and of foreign aircraft for which licences have been obtained. We are building more aircraft and we are building them faster...

"Today we are justified in saying that our industry holds fourth place in the world. Meanwhile, however, new and complicated problems on the international level have arisen, and it may be said that no country can solve all its civil and military supply difficulties unaided... Subsequent developments have amply proved the organizers of the first Salon in 1909 to have been entirely in the right when they stressed its international character. In aircraft and engine construction no land can be self-sufficient, and exchanges between the nations have become inevitable.

"This realisation has greatly encouraged the French aircraft industry during the past year and has led to the formation by a number of Western European countries of the 'Association Internationale des Constructeurs de Matériel Aéronautique' with headquarters in Paris. This Association is now trying to come to agreements with the corresponding national organizations in Great Britain and the USA... We are firmly convinced that the ancient soil of Europe does not contain solely the elements of disintegration, as is contented by many of our more critical spirits..."

French aviation and North Atlantic Treaty.

Georges Héreil, President of the nationalized aircraft works SNCA du Sud-Est, moving spirit of the Association of the French Aircraft Industry and President of the Paris Air Show, must have felt a justifiable satisfaction on the last evening of his 19th Show. The plans of 1946, the prototypes which were received so sceptically in 1949, have given place to quantity production again in France. The glorious "Armée de l'Air" is now getting not only American and British aircraft but also others designed and built in France which can stand up to comparison with present-day equipment from any other country.

But Héreil had another cause for satisfaction on the evening of July 1st. His Paris Air Display had proved beyond all doubt to hundreds of thousands of Frenchmen and to over 2500 distinguished guests from all over the world, that the oft-quoted Atlantic Pact is not a meaningless scrap of paper—at any rate on the aviation front.

This was perhaps the most lasting impression gained from the recent Air Show.

Faster and faster !

The three American B-36 ten-engined long-range bombers which had crossed the Atlantic non-stop and, after a brief halt at a British airfield, had made a demonstration flight over Paris, aroused considerable interest. And the displays by numerous French, American and British multi-engined transports and helicopters enthralled the spectators, many of whom saw here the dawn of a new technical age.

Enthusiasm rose as French, British and American squadrons demonstrated high precision aerobatics in formation at speeds of over 600 m.p.h. And it reached its climax when roughly 150 jet fighters of all three nationalities, in an impressive fly-past over Le Bourget, presented a kind of firework show. Was it their warlike precision, or their battle paint which so fired the enthusiasm of the crowd?

No, it was not the air display in itself that aroused this response. What so impressed the spectators at Le Bourget was the new speeds of which they had read and heard and which they had perhaps seen on the rare occasions a high speed aircraft had flown over the town. At Le Bourget they realised that flight in the sonic region was no longer an experiment or an isolated record performance, that a new day has indeed dawned for air engineering, aircraft industry, air forces—and tomorrow for air transportation.

Speed and more speed—such is the theme of this issue... EEH.

* cf. INTERAVIA Review of World Aviation. Vol. IV, No. 7, 1949, pp. 397—399.

Faster and faster

Evolution of Speed

BY WILLIAM P. BROTHERTON,
RYAN AERONAUTICAL COMPANY, SAN DIEGO, CALIFORNIA

Since Man's beginning, estimated at 500,000 years ago by geologists, we earth inhabitants have been anxious to get places in a hurry. Whether in war or peace, the spoils have always gone to the fleetest. The particular situation might have been Adam outdistancing a sabre-toothed tiger, Hannibal out-flanking his enemy on elephant-back or Doolittle whisking bombs to Tokyo. In most of life's social, political and economic contests, whoever "gets there fustest" gets the business. Few of us, however, realize that *it has only recently been possible for man to attain this ageless desire for fast transportation.*

A good conception of this truism can be obtained if we stop to think that King Solomon, ancient King of Israel, and George Washington, our first President, lived nearly 3,000 years apart. Yet both wore hand-loomed clothes, used animal oil for light, wood for fuel and rode in horse-drawn vehicles. Washington died just over 150 years ago.

Compressed within the last 200 years of our history, a veritable "second" of time, are the advent of Watt's *steam engine* and Walter's *rocket power plant*; the steam engine marking the beginning of fast transportation and the rocket engine punctuating our present progress in high speed flight. Sandwiched between these extremes are the other great heat engines of history, the *steam turbine*, the *gasoline engine* and the *gas combustion turbine*. With these prime movers at our command, we have really begun to move. And these same heat engines have given the world a phenomenal mass of power: America alone possesses the equivalent to the muscular power of 25,000,000,000 men or the entire population of twelve worlds like our own. This gives each American an average of 180 mechanical slaves to do the work which our ancestors had to perform for themselves.

First Machines

Although these heat engines, or machines, may seem to be too complicated for the layman to understand, they are not. No machine is as complex as it appears; most are merely involved arrangements of simple parts which were discovered thousands of years ago. Let's take a look at history and see where our "age of science" got its roots.

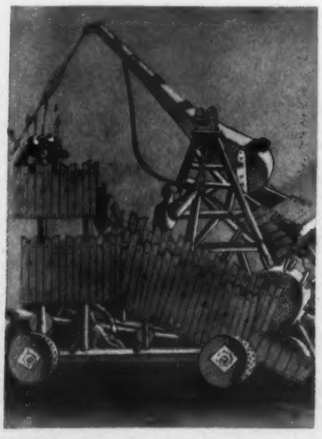
It all began with the *discovery* of the first machine *the lever*. Countless ages ago, some prehistoric experimenter discovered that he could move great weights by placing a pole, or tree branch, over a rock in see-saw fashion and exerting his weight on one end. With this machine, he found he could move weights far greater than his own. Centuries later, the Egyptians used this device, the lever, to raise buckets from wells and fight wars. Today, the lever forms a familiar part of our machines in the bell cranks, rocker arms and crow-bars which we use.

Probably the second machine to come into being was the *wedge, or inclined plane*. We can imagine that this was discovered when another ingenious early man placed a timber against a rock, in ramp-like fashion and found that he could push weights up this slide easier than he could raise them by lifting. It is thought that the Egyptians built the huge pyramids with mammoth ramps, or inclined planes, up which they pushed the huge blocks of stone to their present positions. We find inclined plane applications in the V-pulleys, cone clutches, wedges, screw threads and spiral gears of today's machines.

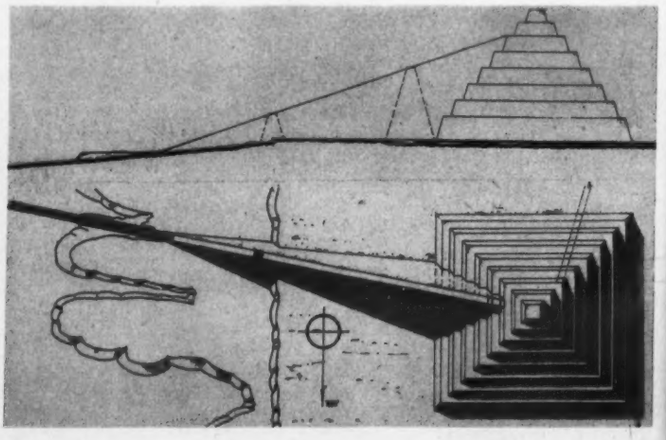
The first *invention* of mankind was the *wheel*. Although no wheel forms are found in nature, undoubtedly the earliest "wheels" were smooth logs which were used for moving weights over the earth's surface. Here, the logs were utilized as rollers in the same manner in which a fisherman rolls a boat out of the surf. Early users of this technique were taking advantage of the physical fact that rolling friction is less than sliding friction.

No one recorded who he was or when it happened, but when the "first inventor" placed a wheel on an axle, mankind began

The first discovery: the *lever*: here it is shown in one of its warlike applications, hurling projectiles into a beleaguered fortress.



The second discovery was the wedge, or inclined plane. The Egyptians used it to build their Pyramids, 2300 years ago.



to roll from one place to another. Records of this type of wheel have been found among Egyptian relics dating back to 2000 B.C. and earlier Chinese civilizations are credited with independent invention of the same mechanism. The wheel so entranced the mind of man that he has spent centuries building machines around it. The roaring propeller of an aircraft engine, the whirling turbine wheel of a giant steam turbine and the pulsing hair-spring of a tiny watch are examples of the rotary motion which characterizes our mechanical world. All about us we see the spinning shafts, gears, flywheels, pulleys and rotors which are the offspring of the first disc. The wheel has not basically been changed in design for over 4,000 years.

With the lever, inclined plane, wheel and a few other similar machines, man struggled along for thousands of years doing the work necessary for his survival. The Egyptians augmented their machines with the muscular power of millions of slaves. The Romans used horses to amplify their sinews. In Holland, wind was harnessed to do work and waterfalls were pressed into service at an early date in China. Meanwhile, transportation had evolved from the sled and man-pulled wagon to the horse-drawn vehicle and the wind-swept vessel.

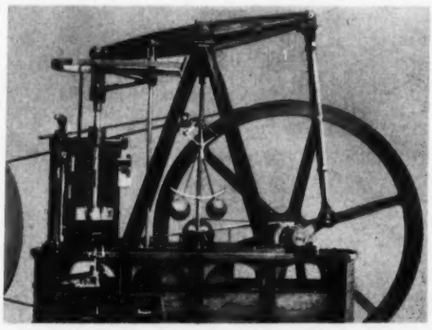
The wheel was man's first *invention* and dates back about 4000 years. It exemplified speed in the Roman chariot.

Heat engines

In 1778, an event occurred which was destined to make all previous sources of energy appear Lilliputian by comparison. The *first heat engine—the steam engine*—was born. James Watt, a maker of scientific instruments, perfected an engine which took the energy locked up in wood, coal and oil and released it to do mechanical work. With this energy, in the form of heat, he produced steam under pressure and channeled it into a cylinder in which he had placed a piston. By a valve arrangement, Watt alternately injected the steam into opposite sides of the cylinder and forced the piston back and forth in straight-line, or *reciprocating motion*. With this machine, he could do little else than operate a pump until he fixed a crank to the piston and attached a wheel. Then he was able to obtain the *rotary motion* necessary for most work applications. Modern steam engines, which power 90 percent of the world's locomotives and 60 percent of the ships, are descendants of this hissing, clanking pioneer.

For the first time, Watt had produced a *machine which made an expanding gas to do the work*. In creating the steam engine, he combined the three elements which are found in all subsequent heat engines: *combustion*, *compression* and *exhaust*. Watt got his combustion from fuel burned under a boiler outside the engine. Hence, the name "*external combustion*" was applied to the steam engine. This early engine wasted 80 percent of the fuel's energy due to heat losses in the boiler and engine. It also developed considerable vibration from its reciprocating parts. In spite of these drawbacks, and the fact that the engine limped along at less than 10 horsepower for a generation, the steam engine changed the habits of the world and provided the first mode of "fast" transportation in steam-driven trains and ships.

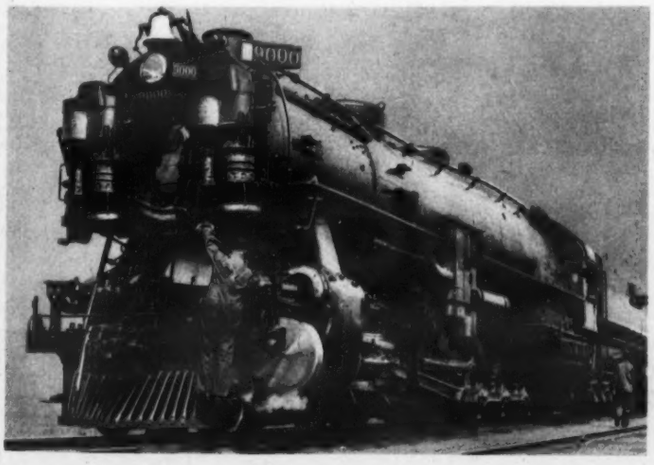
James Watt invented his first steam engine in 1778.

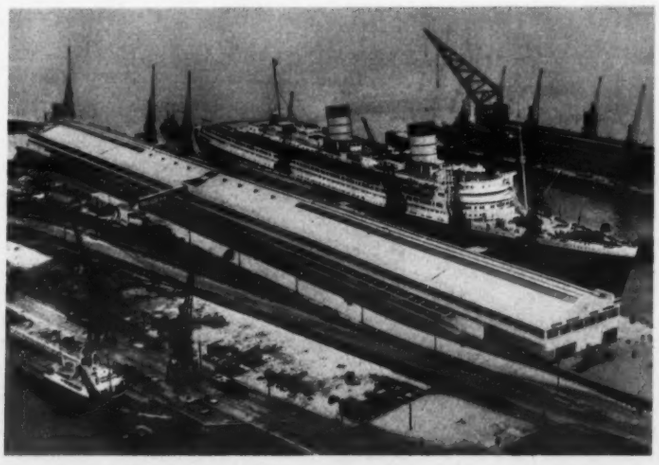


In 1884, the *second great heat engine* came into being with the invention of the first practical *steam turbine* by Sir Charles Parsons. Great promise was held for this new engine because it demonstrated superior efficiency. Using steam obtained in the same fundamental manner as that used in the steam engine, Parsons derived more useful work by *directing the gas against the blades of a steel windmill* whirling on a horizontal shaft. This affair, called a turbine, was spun by the energy of the rushing steam; thus a source of *direct rotary motion*, without reciprocating parts, was born.

With this distinct advantage, the steam turbine is several times more efficient than the steam engine but it has two handicaps for use in transportation. Its peak performance is obtained only in large sizes, because it is more efficient when it can devour a huge flow of steam, and it is best suited for continuous speed operation. For these reasons, steam turbines are found chiefly in stationary power plants and large ships. In these locations, they are performing with an intensity that is hard to grasp. A furious hurricane of hot steam is fed to the 5,000 small blades of the turbine at a velocity of 1200 miles an hour. The turbine spins so

Steam enabled man to travel fast: *Left*, a modern steam-driven train. *Right*, the steam-turbine driven "Queen Elizabeth."

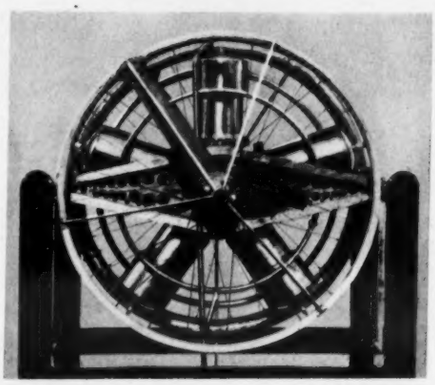




fast that the centrifugal force tending to yank out a single knife-like blade soars to 90,000 pounds. At these velocities, the turbine wheel would roll across the U.S.A. from Coast to Coast in three and a half hours if it were free to travel.

The *third historic heat engine—the gasoline engine*—was invented in 1885. This is the power plant most familiar to the average person—the engine which paved the way for the automobile and later, the airplane. No-one who has listened with anxious ear to the clank of a connecting rod or tap of a sticking valve needs to be told how this engine functions. But perhaps we have not truly appreciated the gasoline engine. For the first time, the design of this power plant placed the burning of the fuel *within the engine itself* so that more heat energy is captured from the chemical source. This innovation accounts for its designation as an "*internal combustion*" type.

As most of us know, fuel for this engine is a hydrocarbon—usually gasoline. It is burned inside the cylinder where the work is done. The gas which performs the job of pushing the piston in this case is not steam, but the products from the explosion of gasoline and air. The pattern discerned in the former heat engines is evident here; combustion is used to obtain a gas under pressure, work is accomplished by using the gas pressure to push a piston and the spent gas is exhausted. The boiler is dispensed with: the combustion gases being employed directly to do the work rather than heat water. This provides a relatively high thermal efficiency but the engine shares one weakness of the steam engine; the *reciprocating piston*. This can be an important drawback in high speed aviation engines, where the pistons must start, stop and reverse several thousand times a minute, because of the friction and vibration encountered.



The first gasoline engines were invented in 1885. The one shown was built by Manly in 1903 to power Langley's aeroplane. It weighed 340 lbs. and had a power of 52 h.p.

The gasoline engine, however, has outstanding features which tailored it to the needs of mass transportation. It works at the relatively low gas pressure of 100 pounds per square inch. Consequently, much less weight is required for its structure. It uses no boiler and water supply and is efficient over a wide speed range. These advantages, plus its low fabrication cost, placed it in the millions of horseless carriages which were waiting for a compact power plant that didn't eat oats. The automobile brought the exhilaration of speed down to a personal basis. It made the expression "go like sixty" the epitome of fast travel and conditioned a generation for the breath-taking velocities which were to come.

The German V-2 rocket projectile has reached 3600 m.p.h.

Air travel

It was inevitable that transportation would take to the air. From the time of the Italian genius, Leonardo da Vinci, who sketched the possibilities of heavier-than-air flight, man had dreamed of becoming airborne. One of the most exciting of the old Arabian Night's Tales concerned the Magic Flying Carpet whose pilot whisked passengers from one nine-foot-by-twelve landing field to another on his pebbleweave conveyance. This yearning to soar found little expression except in the winged figures on the canvasses of the old Masters until the 18th Century. In 1783, the Montgolfier Brothers watched, with wondering eyes, their first important balloon ascent which marked man's adventure into the sky. From this followed a long list of valiant attempts to master true winged flight. John J. Montgomery in America (1883) and Otto Lilienthal in Germany (1891) soared in winged ships from the earth. Then, in 1903, the Wright Brothers accomplished the first powered flight which launched air travel on its meteoric way. Somehow, man had always conceived of flight as the speediest method of transportation because it involved the least friction.

Before the Wright Brothers flew their powered glider they had to select the type of engine they would use. They chose the *gasoline engine* because of its light weight, of paramount importance in an airplane. They built their own four-cylinder engine and used it to spin a propeller in order to thrust the vehicle through space. The propeller had been successfully used for propulsion in another fluid—water, on ships—and it served the same function on the airplane. The Wright's 12-horse-power engine whirled the propeller, which pushed the plane, so that it gathered speed until sufficient air flowed over the wings to create the lift necessary to carry the plane aloft. In this manner the first powered flight was made for a distance of 120 feet—less than the wingspread of a modern bomber.

Aerodynamics

The tremendous progress which has been realized since then in expanding the speed

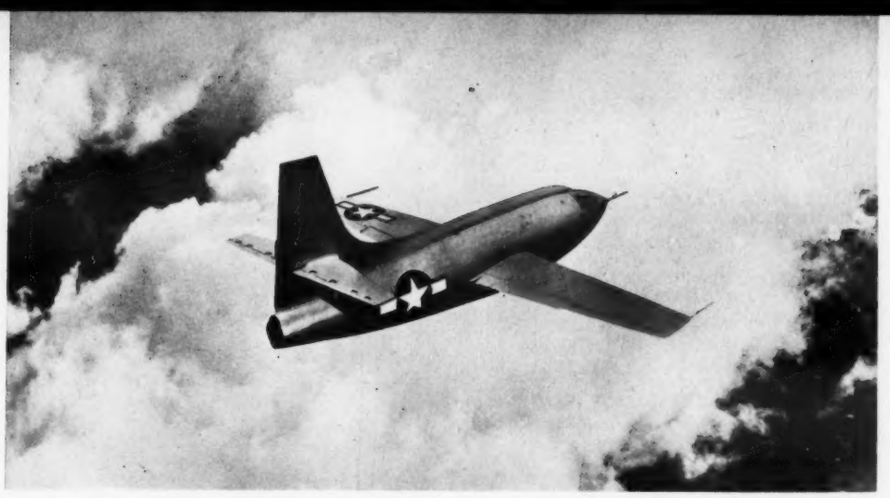
and carrying capacity of the airplane has been channeled into two fields of endeavour: aerodynamics and power. By every conceivable means, the airplane has been made more streamlined or aerodynamically efficient. Early triplanes and most biplanes have given way to the single-wing monoplane design in order that less frontal area should be presented to the air in flight. Familiar strengthening members such as struts, spars and wires have been nestled inside the wing. The landing gear has been retracted into the airplane and the cockpit has been smoothly enclosed. All these steps were taken to allow the plane to zip along with less resistance and greater speed, because it was soon discovered that the shape of the flying structure materially affected its passage through the air.

As aircraft speeds were stepped up from the original Wright Brothers' 30 m.p.h., drag increased because of the simple fact that the air molecules were meeting the flying surfaces at greater velocities. This increase in friction, which occurred at a faster pace than the increase in velocity, was a simple matter to contend with at relatively low speeds. Extra power was crammed into the ship and the design was further streamlined from time to time. But when propeller-driven planes began to reach the 400 m.p.h. mark real difficulty was experienced. A tremendous boost in power was required to push the speed to 500 m.p.h. and there a ceiling seemed to be reached because the propeller tips lost their grip on the air and began to vibrate with ominous warning.

What happens when this occurs is described by engineers as "*compressibility effect*." Essentially, it means that the whole dependable character of the air suddenly changes with devastating force when a body penetrates it at the speed of sound, or 764 m.p.h. at sea-level. Instead of behaving like a reliable fluid and flowing around the travelling body, the air is pushed back so vigorously that it piles up ahead of the surface in a mass of compressed air. This ramming together of the air molecules, without giving them time to flow out of each other's way, results in a pressure wall being built up ahead of the airplane.

The propeller loses much of its ability to act as an air screw, or thrust mechanism, when this temperamental tantrum of the air occurs. The propeller may suffer from compressibility effect at plane speeds as low as 450 m.p.h. because the forward speed of the airplane added to the speed of rotation of the blades brings the propeller tip speed up to the critical 764 m.p.h. speed of sound.

Eliminating the propeller entirely does not solve the problem but does allow the designer to get more speed out of his airplane. Several jet-propelled planes have swooped well past 600 m.p.h. until the air was flowing over certain plane surfaces at 764 m.p.h. Then the roaring, hammering blows of the compressed air waves which signal loss of control and eventual disintegration were experienced. In these cases, the forward surfaces of the airplane, particularly the wing leading edges, compress the air and have to fight the same air battle that the propeller staged at lower speeds. Great masses of compressed air leave the wing surfaces and expand with sudden fury. Like huge chunks of wet snow sliding off a roof, these unpredictable blasts buffet the aft sections of the airplane, sometimes hammering the tail away or chewing great holes in the surfaces.



The Bell X-1 was the first piloted aircraft to fly faster than the speed of sound.

Many ingenious innovations have been resorted to, such as swept-back wings and swept-back propeller blades, in order that pilots may creep closer to the destructive speed of sound. These strategems do not eliminate any part of the compressibility effect problem but merely postpone it until higher velocities are attained. Aircraft will have to crash the sonic barrier in one powerful surge which will carry the craft from 650 m.p.h. to 850 m.p.h. quickly. It is within this general speed range that the air acts both as a compressible and non-compressible fluid, causing so much trouble. With the complete penetration of this danger zone, many engineers believe that greater speeds will be attained by simple increases of applied power.

Of course, several man-made objects have travelled well over the speed of sound. The V-2 bomb has reached 3600 m.p.h. and certain projectiles have been fired at velocities of 4,000 to 5,000 feet per second. The V-2 makes this speed at a 70-mile altitude where it is above 90 percent of the air blanket. Consequently, there is very little air resistance, or drag, to hamper its flight.

It would not be too difficult to construct an airplane in the shape of a projectile which would be capable of supersonic speeds, but the main stumbling block is taking off and landing. Projectiles cannot fly at the low speeds necessary for these rather vital functions. Conceivably, take-off could be managed with jettisonable wings, which could be dropped afterwards, but the prospect of landing a projectile without wings would give any pilot grey hair. One suggested approach is to design a bullet-like airplane with telescopic stub-wings which could be pulled into the fuselage after take-off and extended for landing. This thought has not been translated into an actual airplane but

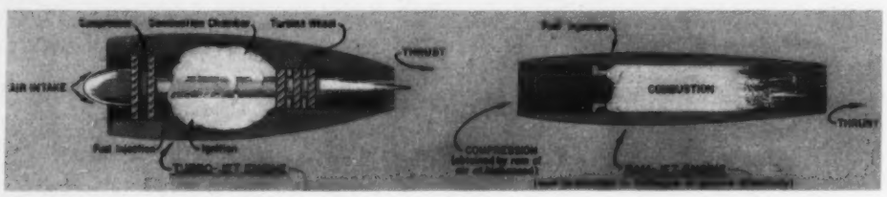
Faster passenger transportation will be made possible by jet-propelled transport airliners. Picture shows the D.H. "Comet."

is an interesting one to contemplate. In any event, we shall not look forward to flight of very much more than 1500 m.p.h. within the atmosphere, because at that speed friction from the airplane passing through the air generates unbearable temperatures which would require elaborate refrigeration.

Outside of the earth's atmosphere, flight is a different story. Without air to impede the journey, speeds of 10,000, 50,000 and 100,000 m.p.h. are theoretically possible. The determining factor is the energy content of the fuel used. Of course, oxygen must be supplied to the engines for combustion, as well as to passengers for breathing in such a space ship which ventured into the void.

Power

Since the inception of powered flight, aircraft speeds have been pushed up an average of 14 m.p.h. per year. In the early aircraft, the limiting factor in attaining higher velocities was the amount of power which could be compressed into a light-weight engine. As power plants became more effective air resistance placed a limitation upon speed. At certain points along the way of air progress, aircraft structures could not stand the stress of speed made possible by powerful engines. This jockeying back and forth between better streamlining and higher horsepower engines has continued throughout aviation's history. Today, the advent of new and mightier sources of power has again placed the onus of holding back flight speeds upon the airplane structure.



Diagrams of a gas turbine jet *(left)* and a ramjet engine *(right)*.

Increases in power have been effected by multiplying the number of cylinders in the gasoline aircraft engine. From the original four cylinders, the internal in-line combustion engine has been increased to six, eight, twelve and twenty-four cylinders. When a practical limit to the length of the crankshaft was reached, the cylinders were radially packed around it in banks totalling nine, eighteen, twenty-eight and so on. During this development, every bit of metal which could be dispensed with was cut out of the engine in order to bring the weight down. Amazing engineering feats have been accomplished with this engine to produce a packaged power plant that would make Aladdin blink his eyes.

With four of these modern engines, a giant airplane weighing as much as four freight cars can be hurtled across the sky at 450 m.p.h. One of United Aircraft Corp.'s 28-cylinder "Wasp Major" engines packs almost as much power as two average passenger train locomotives. You could place it in the cab and it weighs less than the wheels alone. This compact engine, which develops 3800 horsepower and weighs 3400 pounds, could shoot a one-ton elevator up the shaft of the 1250-ft. Empire State Building faster than the speed of sound. One cylinder of these titanic monsters generates more power than most automobile engines. With such power as this, aircraft speeds have been advanced to the point where the pilot is knocking on the wall of compressibility. But, because the gasoline engine depends upon the propeller to translate its energy into thrust, or forward motion of the airplane, it is incapable at this time of exerting that extra lunge necessary to achieve supersonic flight. Just at the time the propeller is called upon for its maximum effectiveness, its efficiency begins to fall away due to compressibility effects.

In addition to the sins of the propeller which fall upon the engine, there is a little problem of heat disposal that is a power plant offspring. To support the volcanic combustion in the cylinders, the engine consumes air like a raging forest fire. This air is rammed into the cylinders where it is instantly transformed from a cool docile gas to a fiery 1600° F. blast which could quickly melt the aircraft's structure. It is one of the tricks of exhaust systems engineering to channel this seething flow from the confines of an enclosed engine to the atmosphere without drag or damage. With increases in power, it has become more difficult to dispose of this heat of combustion from modern aviation engines. Some authorities place the limit of the size of this type of engine for aircraft at 4,000 to 5,000 horsepower because of this factor.

Jet propulsion.

To the men who build planes and fly them, *Jet propulsion* is the biggest single advance in aviation since the beginning. It is the entrance into the final phase of man's effort to propel himself through space.

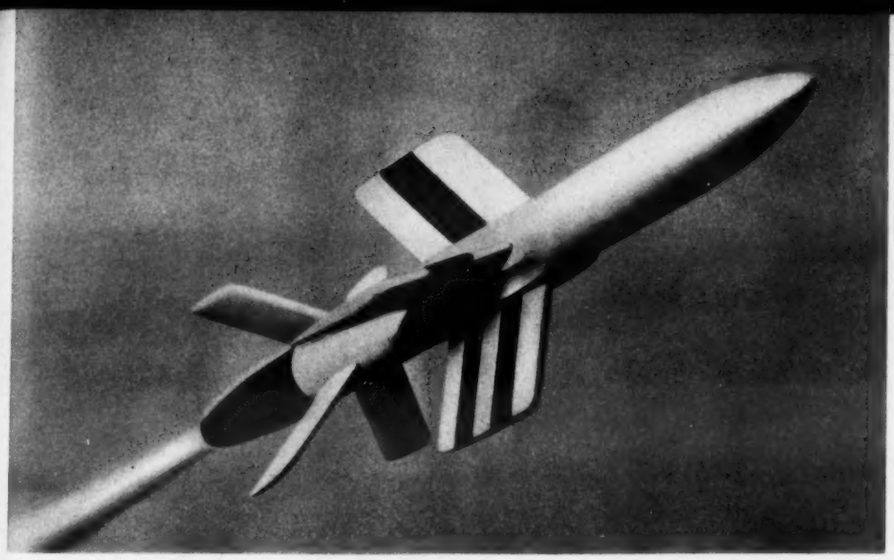
For thousands of years jet propulsion devices have been known. Small toy-like gadgets which emitted hissing jets of steam and spun in the opposite direction were made in ancient Greece. Sir Isaac Newton formulated the principle upon which jet propulsion functions in his third law of motion, and worked fruitlessly on a jet-propelled automobile. Almost everyone is familiar with the antics of a sky-rocket, water sprinkler head and punctured toy balloon. But a useful jet engine was not developed until 1937 because high temperature-resistant metals were not available which could stand the terrific heat experienced in the working parts of this new power plant.

The gas turbine jet engine is a roaring blow torch of an engine composed of a spinning air compressor which sucks in huge quantities of air, packs them into flaming combustion chambers to burn with ignited kerosene and spits the exhaust out of the tail-pipe with the kick of a machine gun. It is one of the simplest of heat engines, having no carburetor, reciprocating parts, supercharger or ignition system for normal operation. It swallows its own cooling air, dispensing with cooling systems. It is harnessed to no propeller, transforming the chemical energy from the fuel directly into thrust for flight. It has only one major moving part; a whirling shaft on which are located the air compressor and the turbine wheel. It will burn almost any fuel which can be blown through a nozzle and burned; from kerosene to powdered coal. Let's take a look at this remarkable engine in action.

In an airplane, the jet engine lends itself to a smoothly streamlined installation in wings or fuselage. Volumes of air ram into its mouth in flight by means of special ducts in the plane. This air is scooped up by the rotating blades of the compressor which packs it more tightly and pushes it into a bank of seething combustion chambers. Here, kerosene is injected and ignited. Combustion occurs with a fierce continuous blaze much like the burning of a blow torch flame, and the expanded exhaust gases are shot to the rear. Before rushing into the tail-pipe, this fast-flowing exhaust whips through the blades of a turbine wheel, causing it to spin. The turbine shaft spins the air compressor located at its forward extremity, causing more compressed air to be fed to the combustion chambers. This sounds like a "lifting-yourself-up-by-the-bootstraps" proposition. Actually, it is an integral air pump driven by a gas turbine.

After the exhaust leaves the turbine blades, it blasts from the tail-pipe at velocities of 1,000 m.p.h., and the airplane recoils from the accelerated stream of exhaust gas. It doesn't make much difference what you use: a stream of water or a flow of gas, but if you expel it in one direction the expelling device will tend to move in the opposite.

In the turbojet, everything is designed to increase the velocity of the air as it passes through the power plant. The reason why fuel is burned with the air is to give it more speed by the expansion of combustion.



The Ryan "Firebird," the USAF's first air-to-air guided rocket missile.

After leaving the turbine wheel, it is squeezed into the tail-pipe to accelerate it further by restricting its cross-sectional area. Kicking the gas out of the tail-pipe at a much greater velocity than it entered the nose of the turbojet, creates the force of reaction or recoil, which is necessary to propel the airplane.

Compared with the other heat engines of history, the turbojet engine has many advantages. It takes the asset of the gasoline engine—*internal combustion*—and combines it with the advantage of the steam turbine—*direct rotary motion*—to form an *internal combustion turbine*. Instead of having several separate components to produce the *combustion, compression and exhaust*, it accomplishes these functions within one unit. The order is changed slightly, with compression coming before combustion.

Basically, the turbojet performs the same function as the propeller. Both accelerate quantities of air rearward and are in turn swept forward by the reactive thrust. At low aircraft speeds, the large propeller can handle more air than the relatively small diameter turbojet. For this reason, jet planes require more area for taking off. At high airplane velocities the turbojet can swallow several times as much air as the propeller can chew. Some of the latest turbojets gulp down two tons of air per minute. And the turbojet makes exceptionally good use of the air it consumes. It employs the same swiftly flowing air stream to feed its fire of combustion, to cool its volcanic parts and to thrust it through space.

A further development in the trend toward greater simplification and faster flying power plants is now in progress. This is the *ramjet* engine. It was realized by engineers that when the turbojet got above speeds of 500 or 600 m.p.h. in flight, the air was ramming down the engine so fast that the turbine and air compressor could be dispensed with and the engine would continue to operate. Actually, the turbine and air compressor are needed only to get enough air into the combustion chambers at the low speeds of take-off to make the engine perform. Following this thought, the exhaust tail-pipe of a jet airplane was taken, modified, and launched into space with a rocket device. When the tail-pipe reached high velocity, its own speed compressed the air rushing in the nose. Fuel was burned with this air and the exhaust was blasted out of the rear. Reaction from this jet stream whipped the tail-pipe up to 1500 m.p.h. At this velocity, the engine developed an equivalent of 3,000 horsepower at the phenomenal weight ratio of one horsepower per half-ounce. Called "the flying stove-pipe with a fire inside," the ramjet is a 70 pound tube without moving parts. It accomplishes *compression, combustion* and *exhaust* with the minimum of time and equipment. Some interesting possibilities can be foreseen for the ramjet. A couple of them could be attached to an airplane which was powered by turbojets. When the airplane attained a speed of say 600 m.p.h., the ramjets would be ready to operate. Here might be a source of great additional power at little weight sacrifice which can be used to crash the sonic barrier.

One of the most sensational types of jet propulsion engines is the *rocket*. This power plant doesn't breathe the atmosphere but carries its own supply of oxygen. The oxygen and fuel are mixed and burned in a combustion chamber. The escaping exhaust is projected through a nozzle and the whole affair is propelled by jet propulsion reaction. This type of engine zooms the V-2 bomb into space for heights of more than 100 miles. Undoubtedly, if anyone makes a trip to the moon, it will be in a rocket-engined conveyance which could operate independently of spatial conditions. Truly high speeds could be enjoyed in frictionless outer space where no atmosphere could hamper your travel and compressibility effects would be left far behind.

Or it might be possible to fire a rocket-engined space ship into the sky at the proper speed and direction so that it would begin to travel around us in a perpetual orbit of its own. If it could get beyond the atmosphere with sufficient reserve power to give it the initial orbital velocity, this would occur. The centrifugal force resulting from its circular zooming around the earth could just balance the gravitational pull of our planet and allow it to wend its way endlessly about us in frictionless space. One handy use for this earthbound satellite would be that it would provide a ready means for setting timepieces—provided that it could be seen.

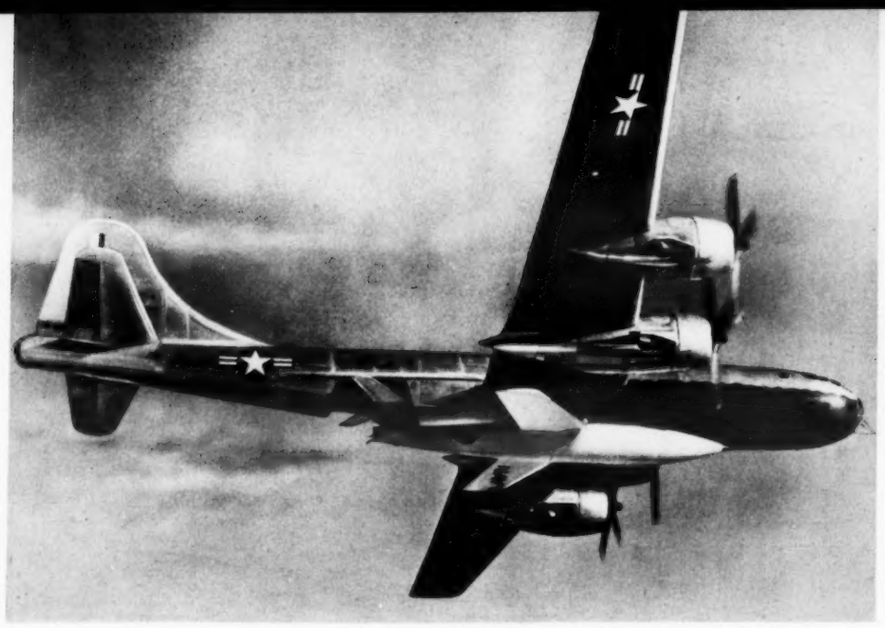
* * *

We have come a long way since the dawn of the lever, inclined plane and wheel. Even the steam engine, the steam turbine and gasoline engine seem to belong to a remote era, separated from the present procession of reaction engines by a new concept in powered propulsion. One by one the obstacles to faster travel have been swept away by science. It begins to appear that the only consideration which will eventually limit the speed and distance of our movement will be the availability of energy in compact fuels. Perhaps that is the appropriate setting for the development of atomic energy fuels.

The US Navy's "Little Joe" rocket of 1946 takes to the air.

Another version of this article has previously appeared in the US "Marine Corps Gazette."

Faster and faster



1500 m. p. h.

Fast, faster—fastest: On July 3rd, 1951, the US Navy announced that during a test flight at Edwards Air Force Base, Muroc, (Calif.), a Douglas D-558-2 "Skyrocket" had "flown faster and higher than any manned aircraft before." To increase the sensation, all the aviation authorities on the US West Coast maintain that the "Skyrocket" reached a speed of roughly 1500 m.p.h. (2400 km/h) at 70,000 ft. (21,000 m).

Immediately after the end of the war Douglas received an order from the US Navy to develop an experimental aircraft for high speeds and very high altitudes. In collaboration with the National Advisory Committee for Aeronautics, Douglas designed the D-558-2 "Skyrocket," a swept-wing derivation of the D-558-1 "Skystreak," also a Navy experimental aircraft. Three years later, on Feb. 4th, 1948, the first "Skyrocket" started its flight tests, followed by two other aircraft of the same type. The few sparse details of the progress of these tests which leaked out indicated that these aircraft repeatedly flew at supersonic speeds.

The "Skyrocket" is an all-metal midwing monoplane with a span of 25 ft. (7.6 m), a length of 45 ft. 3 in. (13.8 m), and a wing area of 175 sq.ft. (16.3 m^2). Its gross weight is roughly 16,000 lbs. (7260 kg). It was originally fitted with a Westinghouse J-34 jet engine of 3000 lbs (1360 kg) and a Reaction Motors Inc. rocket engine of 6000 lbs (2720 kg) thrust. The "record Skyrocket," however, dispensed with the jet, so as to be able to carry additional fuel for the rocket engine. So as to have its entire fuel load available for the actual test flight at high altitude, the machine did not take off under its own power, but was launched from a specially modified Boeing B-29. After the record flight, which made him the "fastest man in the world," Bill Bridgeman, who had previously made 60 flights in the "Skyrocket," said:

"When I dropped away from the B-29, I turned on the rockets and took off at an angle of about 45 degrees. I levelled off and gave it everything it had."

The "Skyrocket" was designed for a maximum speed of 1820 m.p.h. (2930 km/h) and a maximum altitude of 75,000 ft. (23,000 m). The 1500 m.p.h. already reached is probably the highest speed obtained during the flight tests of this aircraft, at any rate so far. Future tests will doubtless aim at translating the calculated maximum performance into reality.

Speed, Air Tactics and Air Strategy

BY CAPTAIN NORMAN MACMILLAN, M.C., A.F.C.

Speed creates new problems

The phenomenal increase in aircraft speeds during the past decade has brought a crop of new problems to the strategist and tactician. These must be solved by senior airmen and experienced ground-staffs, for the day has long gone when strategy and tactics could be invented and applied by pilots during flying operations; the time factor is now too short for success to be achieved that way.

Since the end of World War II fighter speeds have increased by 50 percent, while bomber speeds have gone up by about 65 percent. Thus the percentage speed advantage of the jet fighter over the jet bomber has been reduced, but the fighter has not yet received compensatory armament of a more powerful character. The indication is that the jet-bomber of today is even more likely to evade the jet fighter of today than was the D.4. "Mosquito" light bomber of World War II, which could bomb Berlin in daylight without either fighter escort or defensive armament. The unarmed English Electric "Canberra" is the modern equivalent of the "Mosquito."

It was in the nature of development that jet fighters should be produced before jet bombers. But the consequence is that practical experience in exercises and war has been unbalanced. Jet fighters have had combat experience against jet fighters. So far they have had little chance to discover what they can do against jet bombers, since the latter are only now beginning to make their appearance in first-line squadrons.

So far, the evidence points to increasing difficulty in effective combat between fighters following the rise in speed resulting from the adoption of the turbojet as a prime mover. If this is a direct consequence of the rise in speed, brought about by a reduction in power of manoeuvre coupled with a reduction of the time available for effective fire, it is evident that the same trend will develop in combat between fighters and bombers. The question then arises: can anything be done to increase the armament of fighters in order to raise their effectiveness against jet bombers to the same values as those of piston-engined fighters against piston-engined bombers in World War II.

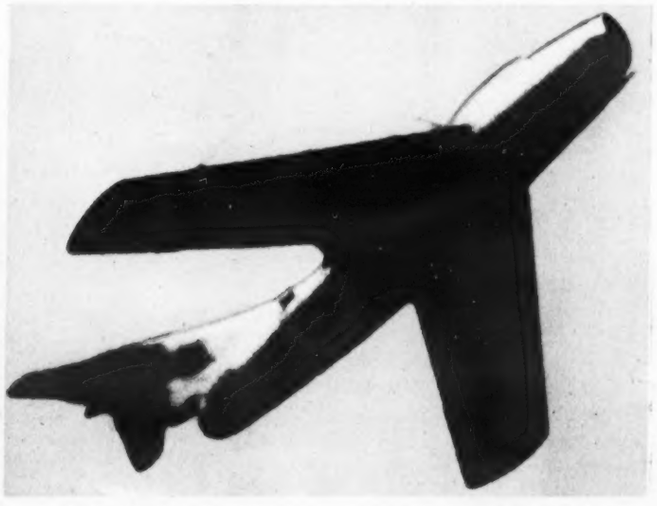
Before probing this question further it is desirable to state some of the *known* conditions and from them deduce the probabilities of the *unknown* conditions that may be encountered in the near future.

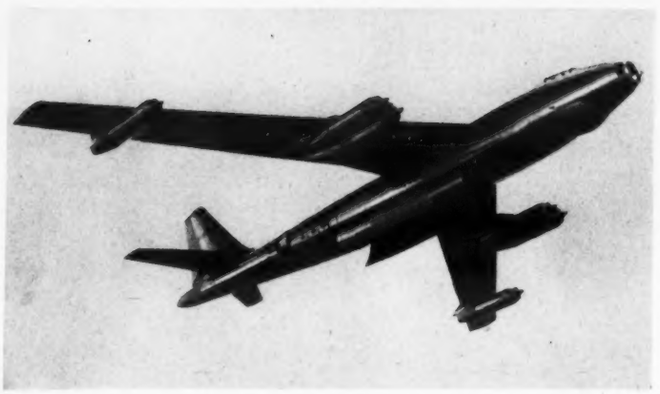
We can divide the known conditions into certain categories: (1) physiological; (2) aerodynamic and engineering; and (3) offensive and defensive.

The human element

The physiological effect of increased speed includes greater gravitational stresses on the body, the necessity for pressurization and oxygenation when flying at height, the need for air conditioning within the cabin, and the risk of explosive decompression arising from combat puncture of the pressurization or the accidental rupture of a canopy. The risk of explosive decompression is difficult to guard against, except by the wearing of a pressure suit in addition to pressurized conditions within the cabin. The personal effect of explosive decompression was described to me by a test pilot who had experienced many failures of a faulty canopy at heights varying from 35,000 to 42,000 feet (10,700 to 12,800 metres). He said it felt like a blow in the pit of the stomach, and at the same time a blow on each of the ears; it was very unpleasant even at these comparatively low levels, and it was necessary to get down quickly; oxygen alone did nothing to alleviate the effects. Death from suffocation may supervene in a few seconds at 63,000 feet (19,200 metres) if pressurization fails, for the atmospheric pressure at that height is too low to permit the breathing of oxygen without artificial pressure; at this height, too, the nitrogen in the blood, which at lower elevations merely bubbles, now boils. (The physiological effect of the blood bubbling is known as "the bends" because of the muscular cramp which produces involuntary bending of the joints). These physiological problems must be solved if aircrews are to operate

Fighter speeds have increased 50 percent since the end of the war. The North American F-51 "Mustang" *(left)*, fastest Allied fighter at the end of the war, had a top speed of 450 m.p.h. The MiG-15 *(right)*, Russian mass-produced fighter, is reputed to develop about 670 m.p.h., the same as the USAF's North American F-86 "Sabre."





But bomber speeds have risen even more substantially. The most modern World War II bomber was the Boeing B-29 "Superfortress" *(left)*, whose top speed approached 400 m.p.h. The USAF's Boeing B-47 "Stratojet" bomber, now in quantity production, reaches a maximum speed of more than 620 m.p.h.

with tactical efficiency and make the most of the potentialities of turbojet aircraft. And for the purposes of this article we must assume that they will be solved, at least to a degree where the casualties due to purely physiological causes are kept down to a reasonably low margin.

Engineering

The aerodynamic and engineering problems concerned with increasing speeds have not been fully solved. Means have to be found to prevent the shuddering which accompanies the near approach to Mach 1.0 on some aircraft. The problem of controllability at high Mach numbers must be solved, for how can a fighter pilot take tactical combat action if his controls are frozen almost solid? Moreover, at these speeds, the aircrew is subject to stresses which are relative; any slight change of direction, even at a low rate of turn, sets up loads which make it impossible to turn the head, or raise it if it is lowered; the power factor of the human muscles can easily be exceeded in the simple manoeuvres of high speed flight. These disabilities may prove the *single-seat fighter to be tactically inefficient at high speed*, because of its relatively poor manoeuvrability and controllability as a fixed gun platform. The fighter of the future may have to be a two-seater, with radar-trained, remote-controlled, power-operated guns mounted in movable gun-chambers, streamlined within the structure, and into which the guns are retractable when not in action. These fighters would also have to be fitted with rocket launching tubes which could be trained by radar sighting to allow for failure to manoeuvre into correct alignment to fire dead ahead. The employment of a larger aircraft as a fighter will also permit the housing of more powerful engines and more fuel for them, and speed need not be sacrificed.

The offensive and defensive conditions may be defined as the development of fighters suitable to the task of intercepting the high-speed bombers of the present day, the development of bomber armament to counter such fighters, the development of ground-controlled interception by homing weapons launched from the ground, together with all the paraphernalia of observation and collation of intelligence, maintenance, industrial backing, and executive control of combined operations for offence and defence.

Importance of Maintenance

Increasing speed in air-war must affect overall strategy, because speed can be employed to increase aircraft utilization, *provided maintenance is raised to equivalent efficiency*. The basic demand is therefore for a considerable increase in the engineering ground services, both in numbers employed and in the equipment provided for field servicing. Without such a stepping-up in maintenance, full use cannot be made of the time factor gained by increased speed for a given operation.

Although maintenance has been simplified by the turbojet power unit compared with the reciprocating unit, it has been complicated by the demand for additional equipment for the aircrew to enable them to operate efficiently in the new conditions of flight. Field servicing echelons should therefore be divided into two kinds: (1) operational servicing echelons, responsible for servicing airworthy operational aircraft on operational airfields, that is, attending to fuelling, guns, rockets, bombs, oxygen, etc. and (2) satellite servicing echelons, responsible for all maintenance work. Satellite servicing echelons should be located at satellite airfields in the vicinity of the operational airfields, and all aircraft returning from an operation in a condition known by the aircrew to be unfit for immediate turn round should be landed at the satellite and not at the operational airfield. Only aircraft believed to be serviceable for another immediate operation after refuelling, etc., should be landed at the operational field.

Satellite servicing echelons should be responsible for the changing of power units, wings, fuselage sub-sections, and component parts, such as undercarriages, air controls, cowling, electronics, fuel tanks, etc. But they should deal only with *replacement* of parts. *Repair work* should be the responsibility of base servicing echelons, and parts in need of repair should be sent back from satellite servicing echelons to base servicing echelons.

In "high-speed air warfare" the quality of maintenance must be adapted to the speed of operation in order to increase aircraft utilization. Picture shows Grumman F9F-2 "Panther" naval jet fighters undergoing field maintenance.

Effect on Strategy

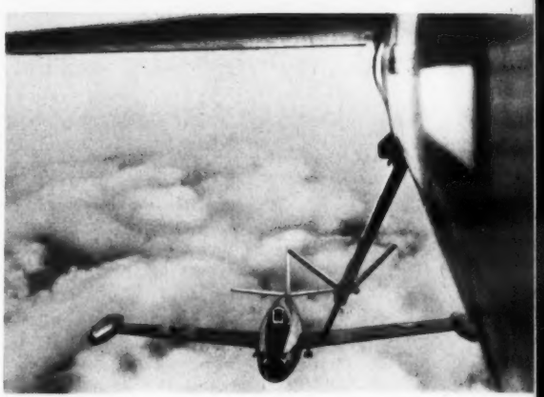
The significant feature of increased air speed for the strategist is the ability thereby presented to increase the fire-power at any given focal point, or series of points, in accordance with any given plan. Whether such attacks are purely strategic in design or form part of a greater tactical plan involving the use of surface forces, the overall time required for a given weight of air action can be reduced, and the factor of surprise thereby heightened. Increased speed may be used to spread attacks over a greater enemy area in a shorter time in order to confuse and dissipate the defence system. But clearly these advantages of increased speed can be fully secured only when the factor of serviceability is maintained at a high level.

The operational staff can plan high speed air attacks to penetrate the defences, without fighter escort or self-carried defensive armament, by combining inherent speed with evasive tactics. The disparity in the recent increases of jet-fighter and jet-bomber speeds favours such a policy, which is still further favoured by the brief flight duration of jet-fighters. *A strategic plan of bomber attacks on fighter airfields and factories, carried out in successive high speed waves, would have a serious attritive effect on fighter defence.*

The Second World War ended with heavy bombers able to make precision attacks from a height, following the development of suitable bomb-sights and bombs with precision trajectories. There is no reason why such tactics should not prevail in future. Accurate bombing of airfields should be possible from great heights, possibly with guided bombs. Ground guns will cease to be useful defensive weapons against these high-speed, high-flying attacks. Guided rockets will take the place of guns for ground defence, and these will have electronic homing warheads. These will be deadly weapons, and it will be essential to the success of offensive air operations to reduce their efficiency to the minimum. As their operation will depend upon radar for intelligence and sighting, it will be the duty of the attack force to blind the radar defences.

Thus, from the beginning of a major war, the strategist must bring into action *the full scale of electronic offensive.* He must be able to blind the radar of the enemy, both to protect himself and to penetrate the enemy defences in order to reach his strategic targets. Aircrews must be trained therefore to navigate without electronic aids when compelled to do so. On the other hand, target identification is so important that when attacking strategically essential targets it may be necessary to drop commandos along a proposed line of route to place electronic beacons to serve as guides to oncoming bombers. *States which are able to organize fifth columns within an enemy State* will possess a great advantage in ensuring navigational aids for their bombers, and the overall strategist must be prepared to take effective counter-action against such activities in his midst.

Not least in the new assessment of strategy and tactics which demands revision to meet the rising scale of speed in air-war is the fact that *ground weapons and logistics have shown little change in speed.* Ships, surface transport and weapons on land move but little faster than in the Second World War, with perhaps the exception of the submarine when submerged. Thus the mobility and increased utilization factor of aircraft, together with improved airborne equipment and weapons, plus the fact that high-speed, high-flying aircraft can move outside the range elevation of all ordinary ground weapons, has increased the dominating nature of air war over all other forms of war. The operational airmen, immersed in their own time element of translational speed, think in three dimensions; the operational soldier, and sailor, faced with this new



The high speed of modern bombers will necessitate standing patrols of defensive fighters. This means flight-refuelling of fighter squadrons. Pictured is the Republic F-84G "Thunderjet" fighter, specially adapted for flight refuelling and now in quantity production, being fuelled in mid-air with the Boeing "flying-boom" type system. Refuelling craft is a Boeing KC-97A "Stratofreighter" tanker.

factor of speed, are compelled to think in four dimensions, an additional complication which must detract from their efficiency. All staffs (including the air staff) must think four-dimensionally. The additional mental strain will be heavy.

Defence air forces will have to be airborne —ready for action. This means employing standing patrols. The brief duration of jet fighters does not favour such a policy without refuelling in flight. If speed-evasion proves more successful than heavy armament for bomber protection, smaller aircraft refuelled in flight will be more successful bombers than larger, slower, heavily-armed bombers. Anti-submarine defence alone does not demand the fastest speeds; here duration to the limit of crew endurance is needed, at moderate operational height, and the pure jet aircraft is not required; duration, manoeuvrability, and weight of armament are essential here.

The burden of the increasing speeds of air-war must be borne by manpower. To maintain the tempo, the ground forces of the air arm must be greater than before, although they are virtually non-combatants in uniform. To maintain the required spares system, industrial output must be greater, and the logistical requirements for air power will increase. Success or failure in war may well flow from the political decisions made in respect of the allocation of manpower to the air arm in all its ramifications. Assuming that the correct decision is taken here (which means that the Chiefs of Staff who are the technical advisers to Governments must have resolved their inter-service prejudices) there can be no doubt that the air strategist and tactician will dominate all military operations except that of the physical occupation of enemy territory, which, however, can be achieved by ground forces only after the air strategists and tacticians of the enemy have been defeated in their own element.

There is no reason why precision attacks from great height, involving the use of electronic bomb-sights and bombs with precision trajectories, should not be employed in a future war. The Convair B-36 heavy bomber was specifically developed for this purpose.

The Speed Demon

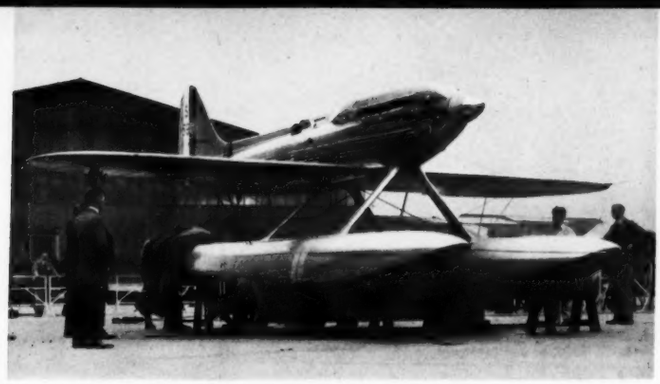
At one time records provided a picture of the peak performance that could be attained at a given time, but did not necessarily reflect the stage reached in normal technical development. Up to shortly before World War II many records were set up by specially designed aircraft and engines, only one of which frequently existed. For example in 1934 the Macchi-Castoldi M.C.72 low-wing monoplane —the fastest aircraft in the world at the time, with extremely fluid lines—was a lone wolf, so to speak, among the crowds of braced and strutted biplanes, many of them still without wheel fairings (the retractable undercarriage was then in its infancy), often even with naked engines lying full in the air stream. Today the whole picture has fundamentally changed. More and more records are being set up by production models (world speed record by North American F-86A "Sabre," one of the U.S. Air Force's standard fighters). It can even be contended that today the official records are often— or could be—surpassed if air forces and industry did not consider it more important to keep real performances secret than to set up new records.

Nevertheless the following survey of speed records amply illustrates the tremendous strides that have been made in aviation since the turn of the century and that will be made in the future—from all appearances at a still greater rate.

Balloons, gliders, powered aircraft.

Any evaluation of present-day performances would be incomplete without a brief reference to the early beginnings, to the transition from the dream of human flight to the reality.

Although there had previously been no lack of projects and "prototypes" of "flying machines" in the "heavier-than-air" class, the first flight by man was made in a balloon on November 21st, 1783. It was not until a century later, in 1890, that the Frenchman Clément Ader's "heavier-than-air" timidly raised itself from the ground* and thus ushered in a period of fierce rivalry between these two classes of aircraft. A bare 20 years later the battle had been decided in favour of the aeroplane. At first it was gliders that came to the fore, such as the model in which Lilienthal made flights of up to 380 yards. At that time airframe construction was far in advance of that of suitable engines. But in 1903 the Wright Brothers broke the ice with the first powered flight. A mere three years later the Fédération Aéronautique Internationale, which had been established in Paris in 1905, recognized the first record. Santos-Dumont set up the world speed record of 41.3 km/h (25.7 m.p.h.). World War I brought the first decisive step forward. Between 1914 and 1918 the aeroplane developed from a "chicken coop" into a serviceable vehicle.



The Vickers-Supermarine S-6B in which Stainforth flew 655 km/h (407 m.p.h.) in 1931.

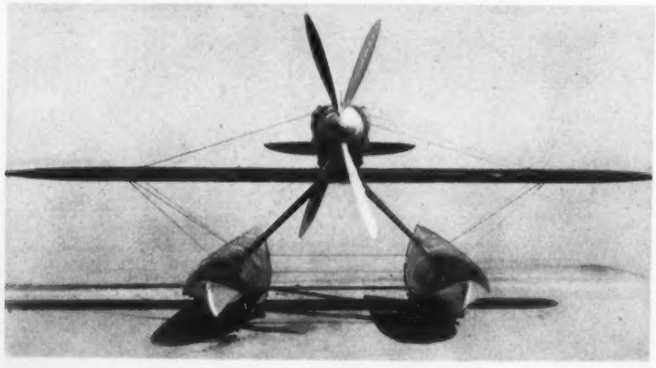
Rivalry between the nations.

The rapid development of speed resulting from the war can be seen from the official list of world records. The last pre-war record, held by France, of 203.85 km/h (126.57 m.p.h.), had been increased to 313.04 km/h (194.51 m.p.h.) by 1920. In 1927 and 1928 the Italian Macchi Works gained world fame with their M.C.52 record-breaking aircraft (512.78 km/h = 318.63 m.p.h.). A year later the British snatched the hotly-contested prize: a Supermarine S-6 seaplane flew at 575.70 km/h (357.72 m.p.h.) and a later model of this aircraft, the S-6B, surpassed this record with a speed of 655.0 km/h (407.0 m.p.h.) in 1931. It should, of course, be stressed that the S-6B—like the Macchi aircraft—was developed specially for the well-known Schneider Trophy Race of the inter-war years. In both cases especially streamlined airframes were coupled with highly-developed engines (Rolls-Royce 2640 h.p. in the S-6B). These low-wing monoplanes already had the lines, round about 1930, which were to reappear later in the fighters of World War II (Supermarine "Spitfire").

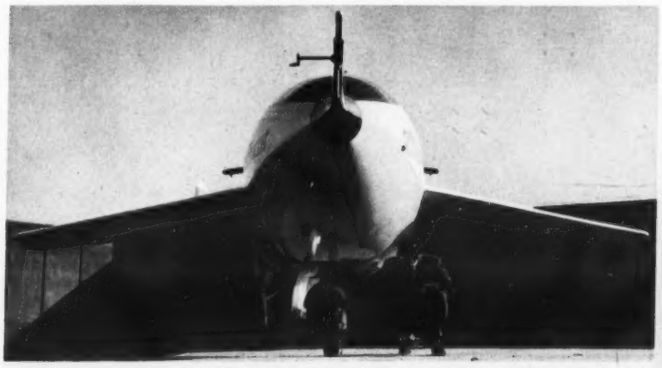
Once again the laurels went to the Italians. In 1933 a Macchi-Castoldi M.C.72 (seaplane) brought the record up to 682.08 km/h (423.83 m.p.h.), and in 1934 this performance was surpassed by another aircraft of the same type with a speed of 709.2 km/h (440.7 m.p.h.). At this point the triumphal progress of the seaplane came to a (temporary?) end. In 1939, shortly before the outbreak of World War II, a German landplane broke the record, which had remained at 709 km/h for five years, when a Heinkel He 112 reached

* Cf. "The First Half-Century of Aviation," by C.G. Grey ; INTERAVIA, Review of World Aviation, Vol. VI, 1951, No. 6.

1934. The Italian Macchi-Castoldi M.C.72 exceeds the 700 km/h mark.



1951 : According to US Navy statement published in July, a Douglas D-552-8 "Skyrocket" has "flown faster and higher than any other aircraft before." Unofficial reports give the speed recently reached by this aircraft as nearly 1500 m.p.h. (2400 km/h).



746.41 km/h (463.80 m.p.h.); and shortly afterwards a Messerschmitt Me109-R brought this up to 755.14 km/h (469.22 m.p.h.).

World War II saw the introduction of jet-propulsion and a new turn of events. Piston engines, whose performance had in many respects been pushed to the utmost limits, were replaced by power plants which, although still in their infancy, were superior in performance to even the most powerful piston engines, with a much lower weight. The jump in the world speed record from 755 km/h before the war to almost 1000 km/h in 1945 is the unmistakable proof of this. Great Britain obtained this record with the Gloster "Meteor 4" twin-engined jet fighter, which flew 976.0 km/h (606.46 m.p.h.) in 1945 and 991.14 km/h (616.0 m.p.h.) in 1946.

Meanwhile the Americans had been putting their wartime experience to good account and brought out several different aircraft to attack the British record. In 1947 Europe had to cede the honour of possessing the fastest aircraft in the world to the USA and so far has not been able to win it back. A specially equipped version of the Lockheed F-80B "Shooting Star" single-engine jet fighter, the F-80R (re-designed wing leading edge, modified air intakes and cockpit cover, Allison J-33-A-23 jet engine of 4600 lbs = 2090 kg static thrust with water injection) reached a speed of 1003.69 km/h (623.8 m.p.h.) and was thus the first aircraft to cross the 1000 km/h line. However, the "Shooting Star's" record was short-lived. Only two months later the experimental Douglas D-558-I "Skystreak," which had been developed for the US Navy, raised it to 1031.18 km/h (640.66 m.p.h.) and five days later to 1047.36 km/h (650.61 m.p.h.).

The world speed record of 1079.84 km/h (670.98 m.p.h.) which has not yet been officially surpassed was set up on September 15th, 1948, by Major Richard L. Johnson (USAF) flying a North American F-86A "Sabre." This was a production model of the "Sabre" which even carried its full combat equipment (armament) on the record flight and was fitted with a production model of the General Electric J-47 engine of 5000 lbs (2270 kg) static thrust.

Even the helicopter puts in its word

All the helicopter records which are still valid today have been set up since the war. And all are held by the Americans. Nevertheless it should not be forgotten that the first helicopter records, dating from 1924, went mainly to the French. It was also the French who did valuable pioneer work in the development of a serviceable helicopter. For example, in 1936 the Bréguet-Dorand helicopter with a 300 h.p. Hispano-Suiza engine gained considerable fame by setting up no less than four records, the altitude record of 158 m

The North American F-86A "Sabre" holds today's world speed record of 670 m.p.h. (1080 km/h).

(518 ft.), the speed record over 20 km measured base, of 44.69 km/h (27.77 m.p.h.), the distance record in a closed circuit of 44 km. and finally the endurance record of 1 hr. 2 min. 50 sec.

Another epoch-making model was the German Focke-Wulf Fw 61 (160 h.p. Bramo Sh. 14 A engine), which flew at a speed of 122.5 km/h over a 20 km measured base in the summer of 1937.

As already stated, all helicopter records since the war have gone to the USA. All have been obtained with the Sikorsky R-5A (Pratt & Whitney R-985 "Wasp Junior" of 450 h.p.) or the S-52-1 (245 h.p. Franklin 0-425-1 engine). Increased engine output (helicopter engines with ventilators for improved cooling), cleaner lines for the airframe and greatly improved and lighter rotor designs have resulted in performances which have left everything that had been done before the war far behind. The altitude record was raised from 3427 m. (1939) to 6468 m (1949; Sikorsky S-52-1); the endurance record with return to take-off base set up by a Sikorsky R-5A in 1946 and still unsurpassed is 9 hrs. 57 mins. and the speed record over 3 km measured base is 208.49 km/h (129.54 m.p.h.—Sikorsky S-52-1).

And today?

The battle for speed, greater altitudes and distances is in full swing. Aircraft for speeds of over 2500 km/h (1550 m.p.h.—Bell X-1A), and even for 3500 km/h (2200 m.p.h.—Bell X-2) are under development or are being prepared for their first test flights. The Bell X-1A, successor to the well-known Bell X-1 experimental rocket aircraft, is to start its flight tests before the end of the year. The Douglas X-3, another experimental type, is to be ready for flight by January, 1952. Incidentally altitudes of 80,000 to 100,000 ft. (25,000 to 30,000 m.) will be considered normal for these forerunners of a new flying age. Even the helicopter will not be left in the cold. Igor Sikorsky's statement that it is already technically possible to build helicopters for a speed of up to 500 m.p.h. (800 km/h) and that solely financial considerations were holding the designers back is a forecast of things to come.

And an altitude record : This aircraft probably holds a "permanent" record : The Caproni 161 bis (piloted by Pezzi) set up an altitude record for piston-engined aircraft of 17,083 m (55,946 ft.) on October 22nd, 1938, which presumably will never be surpassed.

Faster and faster

Flexible Wings in the Wind Tunnel

In the B-47 "Stratojet" six-jet bomber, Boeing engineers have produced what is the fastest bomber in squadron service today. So as to get the required speed of 600 m.p.h. (965 km/h) from an aircraft of this size —a "mere" 185,000 lbs. (84 tonnes) gross weight—they chose a thin wing with large angle of sweep (35 degrees) and a span of 116 ft. (35.4 m). Traditional methods of calculation, which were applicable only to rigid wing units, were quite inadequate for a very thin swept wing. High speed aerodynamic tests had to be combined with elasticity measurements in a new technique to measure what came to be known as "aeroelasticity," *i.e.* special allowance had to be made for the behaviour of the B-47 flexible wings at high speeds.

The wind tunnel tests, made before construction was started, to determine the aerodynamic qualities, were adapted to the wing's structural characteristics. Tests with a rigid model could not have given fully satisfactory results. Therefore the wind tunnel model was made of thin aluminium and balsa wood and designed to give the same degree of flexibility as the full-sized aircraft would have. Thus wing flutter, wing divergence and aileron reversal—phenomena which may occur when certain critical speeds are exceeded, or when com-

Right above : A flexible, or, as the Boeing engineers call it, an "aeroelastic" model of the B-47 being "flown" in the wind tunnel. The flexing of the wings can be clearly seen ; *front left*, the "pilot" behind his controls. Right below : The wind tunnel model of the "Stratojet" being prepared for a "test flight" ; a metal rod forms the backbone of the fuselage.

The suspension system permits the model to move vertically and to pitch and yaw. Wires connect strain gauges and accelerometers in various portions of the model to instruments on the control desk.

pressibility effects make themselves felt—could be measured in the wind tunnel. The model was suspended on a vertical rod in such a way that it had full freedom of vertical movement, pitch and yaw. A "pilot" —at the wind tunnel control desk—"flies" the model by small movements of the controls, and his "co-pilot" tells him his "flying speed" (and Mach number). Strain gauges and other automatic recording instruments ensure continuous recording of all measurements in the various conditions of flight.

These new test methods have resulted in a considerable speed-up in testing and production of the B-47. What is more, wind tunnel tests have thus been brought a good step closer to actual flight testing conditions. The results obtained from the "Stratojet" tests should be of real value in the further development of the B-47 and other bombers which will follow it.

Transparent plastic tanks are used to enable "sloshing" effects of the fuel on stability and controllability of the model to be investigated.

Second Class Air Services

BY RÉGNIER DE WYKERSLOOTH, COMMERCIAL DIRECTOR OF SABENA FOR SWITZERLAND

During 1950 air transport companies throughout the world flew a total of 888,560,000 miles, carrying over 30 million passengers over an average distance of 540 miles, and 570 million tons of freight. Better still, 1950 was the year of marked and decisive improvement in the financial position of the airlines, which seem to have mastered the difficulties of 1948 and 1949, difficulties which had been due to a combination of economic depression and the heavy expense of purchasing and putting into service modern aircraft. The majority of the companies have now covered the cost of renewing their fleets and other initial expenses involved in converting to the new equipment; the new machines carry loads 50% greater than their predecessors at a speed 50% higher, whilst the reduction in indirect operating expenses in relation to flying costs has resulted in more profitable operation. In the USA, where the air transportation industry employs 80,000 persons and represents an investment of $360,000,000, the total operating receipts of the scheduled domestic airlines since 1948 provide a good example of the results obtained:—

1948	$413,000,000
1949	$460,000,000
1950	$511,000,000

At the same time the mail payments made by the Government had been progressively reduced from $2.15 per ton-mile mail carried in 1939 to $1.17 in 1950, for the scheduled domestic companies. Nevertheless even in 1949 the latter recorded a net operating profit of nearly $26,000,000 or an increase of 1150% over 1948.

This eminently favourable position was reached in a large measure by a reduction in rates on the one hand, and by savings in direct operating costs coupled with an increase in the number of seat-miles offered, thanks to the policy followed by the principal American scheduled airlines between 1948 and 1950, of replacing the DC-3s and DC-4s by "Convair-Liners," DC-6s, "Constellations" and "Stratocruisers," on the other. The advantage gained from this modernisation of equipment is shown in the table below, drawn up by American Airlines for the Civil Aeronautics Board at the time of their request for authorisation to open a coach service with DC-6s between New York and Los Angeles.

Direct costs (per mile)	*DC-6 52 seats*	*DC-6 70 seats*	*Increase (+) or decrease (—)*
	Cents	*Cents*	*Cents*
Flying costs	37.45	37.45	—
Maintenance of flying equipment	17.53	17.75	+ 0.22
Depreciation of flying equipment	13.64	13.64	—
Total	68.62	68.84	+ 0.22
Indirect costs (per mile)			
Ground organization	14.02	14.08	+ 0.06
Maintenance on ground	10.15	10.12	— 0.03
Gifts to passengers	10.44	4.28	— 6.16
Traffic-sales service	11.10	11.84	+ 0.74
Publicity	3.04	3.34	+ 0.30
Administration costs	8.37	8.70	+ 0.33
Depreciation of ground installations	2.91	2.96	+ 0.05
Total	60.03	55.32	— 4.71
Total costs	128.65	124.16	— 4.49

These costs, calculated on the basis of a load factor of 60% in both cases, show clearly that an increase in the number of seats offered does not necessarily affect the operating costs. By reducing some of the extras given to passengers the American companies have been able to put into service modern high-speed aircraft with pressure cabins equipped for second class services at greatly reduced rates.

*

Although an increase in traffic resulting from the reduction in rates on the coach services seemed certain, it had to be proved that these rates would actually be used by a new section of the public for whom air travel had hitherto been too expensive. Since passenger revenue amounted at that time to 85.2% of the total operating receipts of the American scheduled domestic airlines, the latter were justified in asking whether an increase in the number of seats occupied would be enough to prevent any large-scale reduction in total operating receipts. For example, if receipts per seat-mile were 6 cents and costs 4 cents, the profit—2 cents—would be reduced by half if the fares were reduced by about 16.65%, or 1 cent, and traffic would have to be doubled to make good this reduction.

Nevertheless a number of American companies obtained authorisation from the CAB to operate coach services on certain well-defined and busy routes, on a small scale at first, at a rate of 4 cents a mile instead of the rate normally charged by the American scheduled domestic airlines as a whole (between 5.9 and 6.2 cents per mile on January 1st, 1949).

The experiment thus made on a small scale and in clearly defined conditions could inevitably have but a limited effect on the general receipts of these companies. It was found, however, that in spite of the necessarily limited field allotted to them, the new services had small influence on the 1st class traffic, and that the introduction of 2nd class aircraft really did create a new group of air travellers from those sections of the population which, being less wealthy and therefore more numerous than the users of 1st class services, are of particular importance in the development of air transport. In 1949, when Capital Airlines was the only company to operate a coach service throughout the year, and American and Delta Airlines had inaugurated such services early in the year, 338,089 passengers had been carried by the scheduled airlines on the domestic network. The load factor on the aircraft operating these services was 72.2%, compared with 52.2% on the 1st class services. This tendency was accentuated in 1950, when during the first quarter of the year Eastern Airlines carried 51,256 passengers on its coach services, or 8% of the total number of passengers carried during the period. The rates for 2nd class services enabled the airlines to compete effectively with the railways, as will be seen from the following comparative table:—

	New York-Chicago Single	*New York-Chicago Return*	*New York-Detroit Single*	*New York-Detroit Return*
	$	$	$	$
Pullman rate	40.89	73.60	30.65	57.45
Coach (2nd class) rail fare	30.71	46.75	23.25	35.45
1st class air fare	44.10 [1]	83.79	30.10 [2]	57.20
Coach (2nd class) air fare	29.60 [1]	59.20	21.00 [2]	42.00

However, the reduction in rates resulted in a decrease in passenger-mile receipts recorded by the scheduled domestic airlines in the USA, as shown by the following table:—

5.75 cents in 1948
5.70 cents in 1949
5.60 cents in 1950

Concurrently with and in proportion to the favourable results obtained, the rate of mail payments made by the Government to these companies was progressively reduced from 127 cents per ton-mile in 1948 to 108 cents in 1950.

It is therefore particularly interesting to note that in spite of the reduction in passenger-mile receipts and particularly in mail revenue, which represents between 50 and 75% of the total receipts of the American scheduled domestic airlines, the latter recorded a profit of $26,000,000 in 1949 and of $52,000,000 in 1950.

There is little doubt that these excellent results must be attributed in large measure to the far-sightedness of the advocates of coach services and to the detailed care with which these experiments were gradually extended in practice, for in order to succeed it was essential to balance the reduction in rates by an increase in passenger-miles, at the same time reducing operating costs. The table below illustrates the relationship between these very different factors and their part in the total result recorded.

Comparison of 1950 and 1949 results for American domestic airlines :

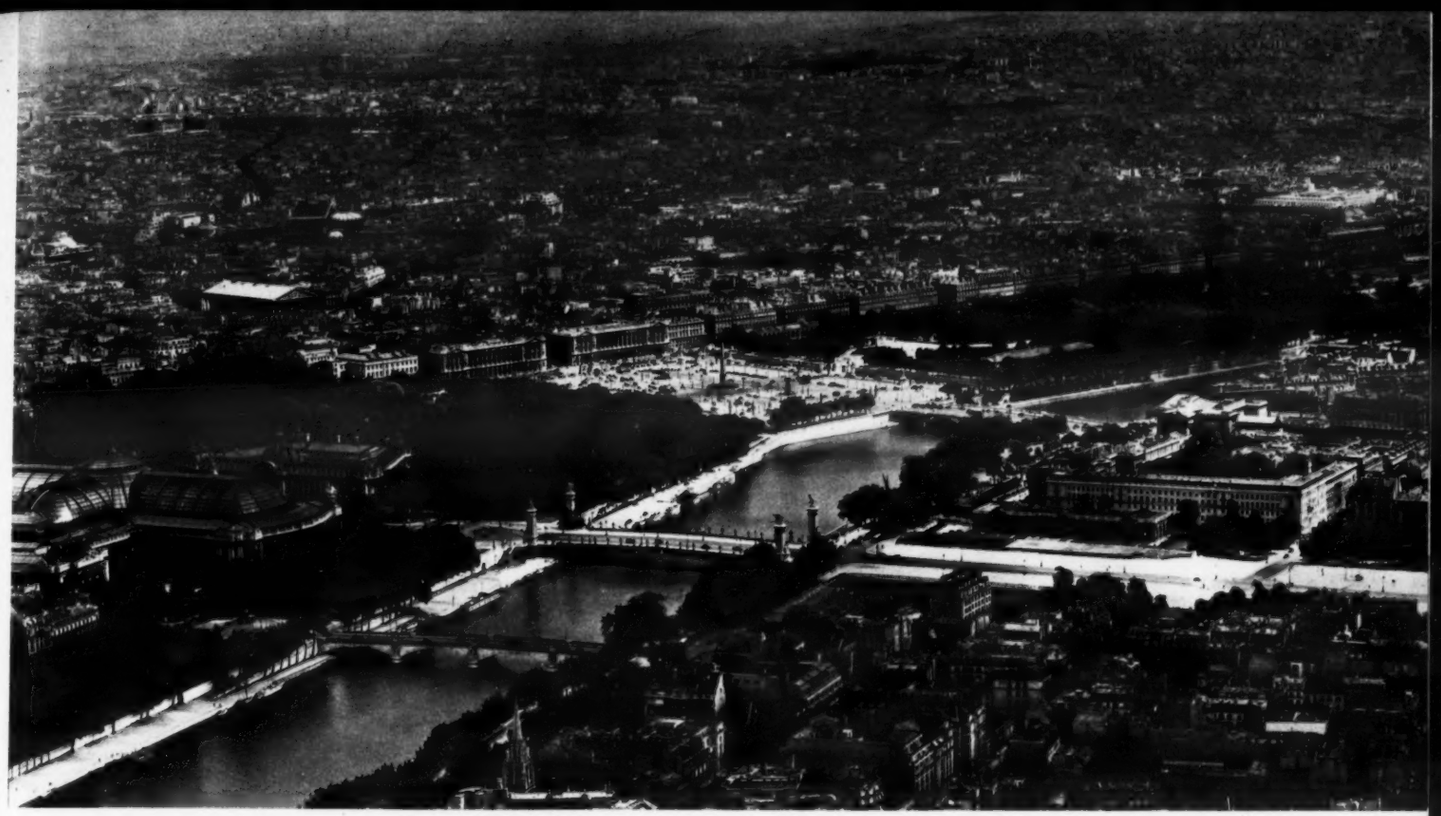
Miles flown	+ 2%
Passenger-miles	+ 18.5%
Passengers carried	+ 14.7%
Receipts (excluding mail payments)	+ 14.3%
Operating costs	+ 8%
NET PROFIT	+ 100%

Since the favourable effect of coach services on the financial position of the airlines had been clearly proved, the CAB could no longer object to such services being opened, under its supervision, by companies operating an international network. Now that experiments have been made on a number of heavily travelled routes, it is legitimate to hope that scheduled airlines will soon introduce this type of service on the inter-continental routes. There is no doubt that those who operate such services will give their greatest attention to the North Atlantic since the economic and ideological bonds between the continents of America and Europe are becoming closer and closer, and commercial aviation, in its capacity as a public service, has a vital part to play in rendering these essential contacts more rapid and more numerous, while at the same time placing them within the reach of an increasingly large number of travellers. Moreover, this part of the world offers air carriers conditions which are at least as favourable to the development of this class of transport as does the USA itself, firstly in traffic potential, since the majority of the two million persons who passed through the US Customs during the 1948-1949 fiscal year were travelling to or from Europe and that over half of these had travelled by air; and finally by the capacity offered by the airlines, which has increased from 176,000 seats in 1948 to 220,000 in 1951.

In addition, the fact that 94% of trans-Atlantic air passengers in 1949 had incomes of over $5000 a year, and that there are 15 million American families with annual incomes of between $3000 and $5000, would seem to indicate that the provision of reduced trans-Atlantic rates would open up a new and practically inexhaustible market for the airlines concerned in these routes, especially as 30 million American citizens were born in Europe or of European parents and that only 1% of these ever go to Europe at present. This latter section of the population also represents a considerable traffic potential, illustrated by the fact that in 1950 the scheduled airlines carried 171,486 passengers from Europe to America, against 145,341 in the opposite direction, in spite of the fact that the fare across the Atlantic falls more heavily on Europeans than on Americans whose incomes are generally higher and who are also more familiar with air travel and with long-distance travel in general. In addition Europe yearly provides a considerable number of emigrants and students, many of whom have hitherto travelled by non-scheduled airlines, whose different conditions of operation enable them to offer lower rates than the scheduled companies.

Before coach services can be introduced on the North Atlantic there are a number of problems which must first be solved. The discussion of these problems falls outside the scope of this article, but not the least of them is that of the flying equipment. Nevertheless, young as is commercial aviation, it has amply proved that full confidence can be placed in its sureness of judgment, boldness of concepts and dynamism, and that the industry, the most international in the world, can be relied upon to play its part in the creation of a better world.

[1] Fares published by Trans World Airlines.
[2] Fares published by Northwest Airlines.



Bird's eye view of the centre of Paris: Grand Palais (left), Place de la Concorde (centre) and Esplanade des Invalides (right) with Aérogare. The photo was taken with a SFOM air camera, type 34, with a focal length of 19 3/4 in. (500 mm) (stop 4.8 ; yellow filter).

The Paris Air Show

"Speed and precision" could well have been the motto of the 19th International Aircraft Show in Paris... particularly of the air display with which it concluded on July 1st, 1951. Virtually everything of note in the aviation world took part in the display at Le Bourget: giant commercial transports, jet-powered airliners, fighters, fighter-bombers, night fighters, jet bombers, heavy bombers, sports aircraft, trainers and experimental aircraft. More and more types were lined up for inspection at the airport during the last few days of June, until on the closing day there were 35 of them, or roughly twice as many as were on show in the Grand Palais.

Wisely the Association of the French Aircraft Industry had announced from the beginning that the traditional show in the Champs-Elysées would this year be supplemented by a "Static Show" at Le Bourget and by the flying display. The highly-polished exhibits in the Grand Palais—so artistically arranged amidst flowers and fountains—thus had more realistic counterparts at the open-air show. Aircraft are really not at home on carpets, but must be seen in the air or at the very least on aerodromes.

Incidentally there were very few prototypes or projects in the Grand Palais this time, and such as there were came solely from private firms, since the French nationalized factories are fully occupied with the quantity production of proven types. The most interesting exhibits in the city were clearly the jet power plants, piston engines, accessories, radio and radar equipment.

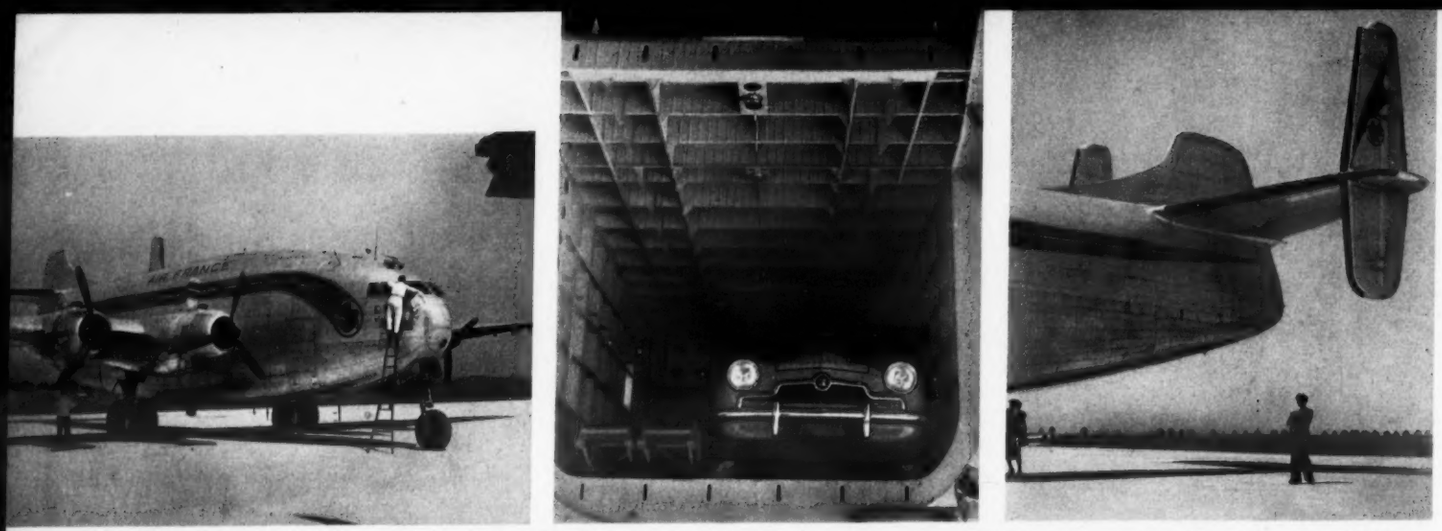
Speed? Roughly a dozen jet fighters and one jet bomber in the Show reached speeds of over 560 m.p.h. (900 km/h) in level flight, and three of them exceeded 620 m.p.h. (1000 km/h). The maximum speed of two of the commercial transports ("Comet" and "SO 30 Nene") was over 435 m.p.h. (700 km/h) and of two others ("Viscount" and "Armagnac") over 310 m.p.h. (500 km/h).

Precision? You could have set your watch by any of the events in the display. Each began and ended punctually to the second and the whole programme, in which over 250 aircraft took part, was completed in 3½ hours.—Many aircraft came, either singly or in formation, from distant bases in Britain, Western Germany or the Mediterranean. The precision of the formation flights, particularly the group aerobatics, was beyond all praise.

Although the biggest contribution to the Show was, as usual, made by the French industry, the Armée de l'Air and the Aéronautique Navale, the international character of the event was nevertheless maintained by the presence of American, British, Italian and Dutch aircraft and crews, particularly at Le Bourget. British turbo power plants, American, British, Italian piston engines and pro-

In the Grand Palais there were a few aircraft—but a large number of models—on show, together with turbojets, engines, equipment, ground installations. From left to right: Fouga "Lutin"; fuselage of the Nord 2501 "Noratlas"; Dassault MD 450-R "Ouragan" fighter-reconnaissance aircraft; Sud-Ouest SO 1120 "Ariel III" jet helicopter; Hurel-Dubois HD 10 experimental single-seater.

With its span of 39 ft. 4½ in. (12 m), the Fokker S.14 two-seater trainer was the largest aircraft on show in the Grand Palais. The trainer is fitted with a Rolls-Royce "Derwent 9" (of 3600 lbs. = 1630 kg thrust) and ejector seats. Six nylon tanks in the wings (capacity 400 Imp. gals. = 1820 litres) give it an endurance of 2 1/3 hours; max. speed 440 m.p.h. (710 km/h), landing speed 80 m.p.h. (130 km/h).



One of the new Bréguet 763 "Deux Ponts" freighters, whose lower deck is equipped for the carriage of the most bulky goods—e.g. three Simca 9 cars. Left, the window-cleaner at work ; right, a visitor appears to be wondering how the mechanics can reach the tail for maintenance work.

pellers, and last but not least a large number of foreign accessories and radio instruments were to be seen alongside French products of the first quality.

COMMERCIAL AND MILITARY TRANSPORTS

Practically all existing transport types were shown in the Grand Palais in the form of models, but the present review will be restricted to the full-size commercial transport types that were to be seen at Le Bourget. Greatest interest was shown in the two giant transports, the SE 2010 "Armagnac" and the Bréguet 763 "Deux Ponts."

Fitted with four Pratt & Whitney R-4360 B.13 "Wasp Major" four-row radial engines of 3500 h.p. each, the *SE 2020 "Armagnac"* has a span of roughly 160 ft. (49 m) and a wing area of 2,543.5 sq.ft. (236.3 m²). At a gross weight of 165,340 lbs (75 tonnes) the take-off run to clear a 50 ft. (15 m) obstruction is only 4,985 ft. (1520 m). The sound-proofed pressure cabin has seats for 84 passengers on 1st class services or 107 on 2nd class. Cruising speed (at 1725 h.p. per engine) 267 m.p.h. (430 km/h); range (with 12,790 lbs. = 5800 kg payload) 3,730 miles (6000 km); crew of seven. A "Super-Armagnac" to be fitted with propeller turbines is being prepared.

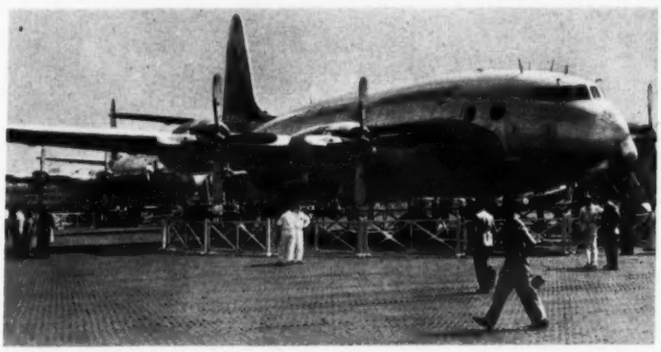
Compared with the "Armagnac" the *Bréguet 763 "Deux Ponts"* has a much more roomy fuselage but a smaller span (approx. 141 ft. = 43 m), and wing area (1,990 sq. ft. = 185 m²). Also a four-engined machine, it is fitted with two-row radials—P. & W. R-2800-CA.18 "Double Wasp" of 2,400 h.p. Its maximum gross weight on take-off is 105,820 lbs. (48 tonnes), which enables it to carry 33,100 lbs. (15 tonnes) of freight over 1300 miles (2100 km)—including ATA reserves. A passenger version for 106 to 130 passengers and a mixed version are under discussion. Cruising speed 225 m.p.h. (360 km/h); crew of three.

There were equally dense crowds round the twin-engined *Nord 2501 "Noratlas"* transport built by the SNCA du Nord (Bristol "Hercules 739" of 2030 h.p. each), which with its gross weight of 42,990 lbs. (19,500 kg) can carry 11,685 lbs. (5500 kg) of freight over 935 miles (1500 km)—with ATA reserves—in civilian operations. In military use its load can be higher. Span 106 ft. 7 in. (32.5 m), wing area 1,083.7 sq.ft. (100.7 m²), cruising speed (at 810 h.p. per engine) 208 m.p.h. (335 km/h).

Three of the *SO 30 P "Bretagne"* medium-stage commercial transports of the SNCA du Sud-Ouest were on show. This aircraft is well-known to our readers. Engines: P. & W. "Double Wasps" of 2000 or 2400 h.p.; span 88 ft. 3 in. (26.9 m), wing area 928 sq.ft. (86 m²), gross weight 39,680 lbs. (18,000 kg), 30 or 43 passengers, pressure cabin, cruising speed 258-273 m.p.h. (415-440 km/h).—Close by was the experimental *"SO 30 Nene"* with central fin and rudder unit and two Hispano "Nene" jets. Experience gained with this aircraft is to be used as a basis for the development of French jet-powered commercial transports. Maximum speed 466 m.p.h. (750 km/h).

The USA sent one of their famous *Fairchild C-82 "Packet"* transports (P. & W. "Double Wasp"), whose giant fuselage could be seen equipped for troop transport, supplies or ambulance service. Span 106 ft. 7 in. (32.5 m), wing area 1400 sq.ft. (130 m²), max. take-off weight 54,000 lbs. (24,500 kg). Great Britain had used an elderly *Vickers "Valetta"* transport (military version of the "Viking" with two Bristol "Hercules" engines) as "staff coach" and had parked it on the exhibition ground, whilst the spectacular commercial transports, the de Havilland "Comet," Vickers Armstrongs "Viscount" and Bristol "Brabazon," made only a flying visit to the Show.

Finally a word on the interesting *HD 31 narrow wing project* of Hurel-Dubois, which was shown in model form at the Grand Palais. With two engines of no more than 800 h.p. it is to be capable, thanks to its very high aspect ratio (20.2) and aerodynamically stressed struts, of carrying 8,380 lbs. (3800 kg) useful load over 620 miles (1000 km), or 6,170 lbs. (2800 kg) over 1240 miles (2000 km). —Span 147 ft. 8 in. (45 m), wing area 1076 sq.ft. (100 m²), gross weight 29,760 lbs. (13,500 kg).



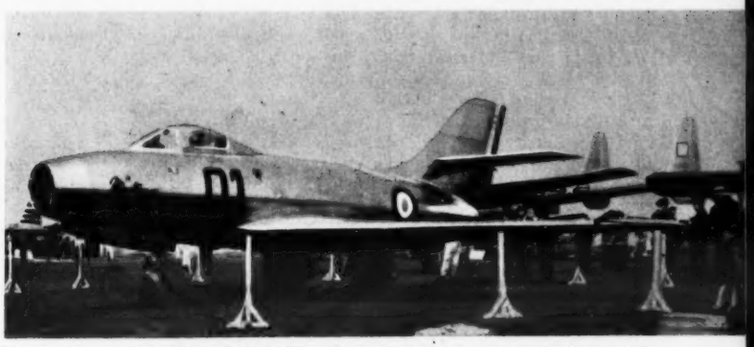
Two Sud-Est SE 2010 "Armagnac" long-range commercial aircraft (84 passengers) lined up for inspection.

The Nord 2501 "Noratlas" military transport, with, behind it, the English Electric "Canberra B.Mk.2" jet bomber.

Sud-Ouest SO 30 P "Bretagne" commercial transport for 30 or 45 passengers.

Martin B-26 "Marauder" flying test bench ; lateral air intakes for the SNECMA "ATAR 101" engine in the rear of the fuselage ; a battery of compressed air bottles in the nose.

"Vampire-Mistral" fighter-bomber of the SNCA du Sud-Est, with Hispano "Nene"; max. speed 575 m.p.h. (925 km/h).



The prototype of the Dassault MD 452 "Mystère" single-seater, swept-wing version of the "Ouragan" with Hispano "Nene," recently reached a speed in level flight of 633 m.p.h. (1020 km/h).

JET FIGHTERS AND JET BOMBERS

Whereas only one proven and one half-finished jet fighter were to be seen in the Grand Palais—Dassault MD 450-R "Ouragan"; wings, tail and model of the Fiat G.80 two-seater fighter—nine other types were demonstrated in flight and some of them could be inspected by the public.

Particular interest was, of course, shown in the first prototype of the *Dassault MD 452 "Mystère,"* the swept-wing version of the "Ouragan." This new fighter had reached a speed of 633 m.p.h. (1020 km/h) (Mach 0.92) in level flight over Istres on June 22nd, and was shown to the public for the first time at Le Bourget. So far it is still fitted with the Hispano "Nene," but is later to have a more powerful jet engine— Hispano "Tay" of 6,250 lbs. (2,850 kg) thrust or SNECMA "ATAR 101" of 6,170 lbs. (2800 kg). Armament is to be four 20 or 30 mm guns; ejector seat and pressurization.

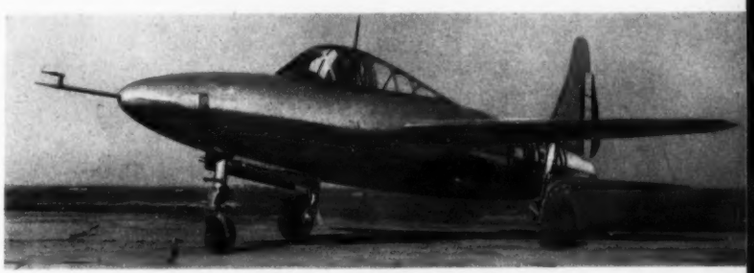
On the other hand the *Dassault MD 450 R "Ouragan"* armed reconnaissance aircraft formed one of the chief attractions in the Champs Elysées. This special version, the eighth aircraft of the production series, differs from the others in that it is equipped with three air cameras in the place of the main fuel tank, which is replaced by two fixed streamlined tanks underneath the wings and two drop tanks at the wing tips. Armament: two 20-mm guns instead of four. The power plant is also a Hispano "Nene" of 5000 lbs. (2270 kg) thrust, and ejector seat and cabin pressurization are provided. Span 40 ft. 4 in. (12.3 m), wing area 251.9 sq.ft. (23.4 m^2), gross weight increased to almost 15,400 lbs. (7 tonnes).

The "Nene-Vampire" shown by the SNCA du Sud-Est under the designation *Vampire Mk.53 "Mistral"* was another novelty. The air intakes had been enlarged for the "Nene's" two-sided radial compressor and the design of the wing correspondingly modified. Result: a speed 47 m.p.h. (75 km/h) higher than that of the "Goblin-Vampire" (*i.e.* 575 m.p.h. = 925 km/h).

The Sud-Ouest *SO 6021 "Espadon"* heavy swept-wing fighter—also with Hispano "Nene"—is a lighter version of the well-known SO 6020 prototype and has modified air intakes. Considering the good performance of this prototype (and of the SO 6025 with "Nene" and liquid rocket) it is surprising that it is not yet in quantity production.

Finally, there were the *Republic F-84 E "Thunderjets"* (Allison J-35-A-17 of 5000 lbs = 2270 kg thrust) with wing-tip tanks, which was the only foreign service fighter open to inspection: span 37 ft. 5 in. (11.4 m), gross weight 20,000 lbs. (9000 kg), max. speed 620 m.p.h. (1000 km/h). Seeing that photographers of all nationalities were permitted to operate freely, the pilots of the Gloster — A.W. "Meteor N.F. 11," Vickers-Supermarine "Attacker" and de Havilland "Venom N.F." preferred to visit a different part of the airport.

The only jet bomber at the show was the three-seater *English Electric "Canberra B. Mk. 2,"* a very slender, fierce-looking black and white bird of prey, fitted with two "Avons" of 6,600 lbs. (3000 kg) thrust; span 64 ft. (19.5 m), gross weight 44,000 lbs. (20 tonnes), max. speed 600 m.p.h. (960 km/h).—Next to this was the *Martin B-26 "Marauder,"* a twin-engined bomber of World War II equipped as a flying test bench for a SNECMA "ATAR 101" jet engine fitted in the rear of the fuselage. During the flying display the "Marauder" flew with stationary propellers, *i.e.* on the jet engine alone.



"Espadon" fighter prototype of the SNCA du Sud-Ouest with Hispano "Nene" and swept wing; max. speed 620 m.p.h. (1000 km/h).

Fokker S.13 "Universal Trainer" six-seater (two P.&W. "Wasp" of 600 h.p.) for training of pilots, navigators, radio operators and bomb aimers; max. speed 220 m.p.h. (335 km/h).

Morane-Saulnier MS 703 liaison six-seater (two SNECMA-Argus As 10 C of 236 h.p.); max. speed 186 m.p.h. (300 km/h).

The Fouga CM.82-R "Lutin" single-seater racer (two Turboméca "Palas" jets of 330 lbs. = 150 kg static thrust each) is also used as flying model for the CM.821-R ground support trainer (hence the guns and rockets) and is said to reach a max. speed of 310 m.p.h. (500 km/h).

ADVANCED TRAINERS AND LIAISON AIRCRAFT

In this field the *Morane-Saulnier* works (Puteaux, Seine) has long enjoyed international fame. They supply the French Air Force with a large proportion of its basic trainers and liaison aircraft, whose all-metal construction makes them particularly suitable for the tropical countries of the French Union. The firm showed their most up-to-date three-seater trainers, the *MS 731* at the Grand Palais and its sister type, the *MS 733* at Le Bourget. Each is fitted with an Argus Salmson 8 As 02 engine of 250 h.p., and v.p. propeller; their max. speed is 160 m.p.h. (260 km/h).—The twin-engined six-seater *MS 703* liaison aircraft (engines Argus As 10 C of 240 h.p. each) was also on show at Le Bourget, both on the ground and in flight; max. speed 185 m.p.h. (300 km/h).

Other French trainers were the *Nord 2800* all-metal three-seater with Argus As 10 C engine (max. speed 155 m.p.h. = 265 km/h) and the high-powered *SIPA S.12* (and S.111) two-seater, two sturdy all-metal designs with 445 h.p. Renault 12 S 02 engine and Ratier v.p. propeller (max. speed 200 m.p.h. = 320 km/h) —The interesting *Fouga CM.82-R "Lutin"* prototype, a mid-wing monoplane of mixed construction designed by Mauboussin and fitted with two Turboméca "Palas" jets under the wings, was shown at the Grand Palais. A direct successor to the single-engined "Sylphe" and "Cyclope," it too has a butterfly tail unit. The "single-seater racer" shown is also to serve as model for a 33% bigger ground support aircraft, the CM.821-R, to be fitted with two Turboméca "Marborés" of 880 lbs. (400 kg) thrust each.

Foreign trainers were there in strength: *Italy* was represented by the latest production series of the *FIAT G.59-4B* two-seater fighter trainer (Rolls-Royce "Merlin T 24" of 1600 h.p., max. speed 373 m.p.h. = 600 km/h), the single-seater version of the *Fiat G.46-3A* all-metal trainer (Alfa-Romeo 115-1 ter of 225 h.p.; max. speed 194 m.p.h. = 312 km/h) and the wooden *SAI-Ambrosini S.7* (Alfa Romeo 115-1 ter of 225 h.p.; max. speed 227 m.p.h. = 365 km/h) in its single-seater and two-seater versions. In addition the SFCA (Lignel) showed the twin-engined *Macchi M.B.* 320 wooden six-seater (185 h.p. Continental; max. speed 200 m.p.h. = 320 km/h), for which it has obtained the production rights, under the designation "Vema 51."

The Fokker Works, of *Holland*, aroused considerable interest with their two-seater *Fokker S.14* jet aircraft (with Rolls-Royce "Derwent"), specially developed for fighter training. Here the budding fighter pilot is given an aircraft with a low landing speed and a fuel supply sufficient for over two hours, an important psychological factor; max. speed 440 m.p.h. (710 km/h); service ceiling 40,000 ft. (12,000 m); ejector seat; no armament.—In addition the versatile *Fokker S.13 "Universal Trainer"* six-seater (two P&W "Wasps" of 600 h.p. each) was demonstrated on the ground and in flight. Max. speed 220 m.p.h. (355 km/h). Lastly a two-seater version of the *Lockheed T-33A "Shooting Star"* (USA) paid a brief but impressive visit to Le Bourget; max. speed 590 m.p.h. (950 km/h).

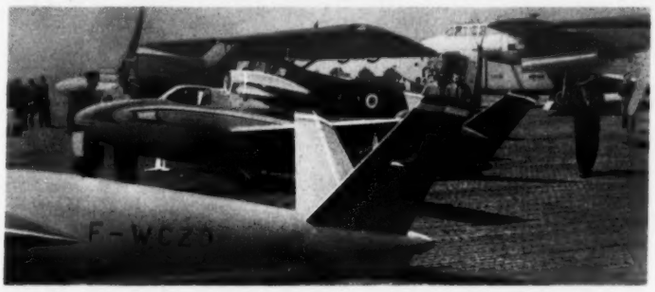
SPORTS AIRCRAFT AND ELEMENTARY TRAINERS

Although sports flying is experiencing a serious crisis, at any rate in Europe, there were nevertheless six French and five foreign types on show, some of them with several variants. Doubtless their makers are counting on increasing attention being given to the elementary training of future aircrews. Above all there was Fokker with its *S.11 "Instructor"* two-seater elementary trainer (mixed construction; 190 h.p. engine), Piaggio with the new *P.148 two-seater* (all-metal; 190 h. p. engine) and *Fouga* with its jet-powered (Turboméca "Palas") "Cyclope I" and "Cyclope II" acrobatic trainers, which have a max. speed of 205 m.p.h. (330 km/h). Old acquaintances included the *SIPA 901* and *Macchi M.B.308* two-seaters, both wooden constructions for engines of 75 to 90 h.p. *SIPA* also showed the (uncompleted) *S.200 prototype* of a two-seater jet-powered all-metal mid-wing monoplane (Turboméca "Palas") for cruising speeds of approx. 235 m.p.h. (380 km/h), and *Hurel-Dubois* its *HD 10 narrow-wing single-seater* (75 h.p. engine) with a span of 29 ft. 4 in. (12 m) and a wing area of 48.4 sq.ft. (4.5 m²), *i.e.* an aspect ratio of 32.5.

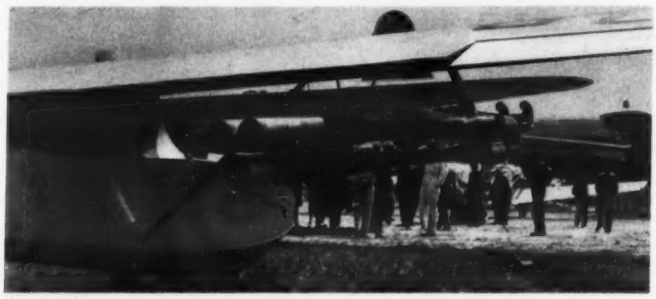
French multi-seaters on show included the attractive *Boisavia "Mercurey"* four-seater (wooden construction; 165 h.p. engine), the new *Aubert PA 204 "Cigale Major,"* also a four-seater (wooden construction; 140 h.p. engine), and the elegant *Sud-Ouest SO 7060 "Deauville"* three-seater (all-metal construction; 105 h.p. engine). Finally the American *Cessna 170* all-metal four-seater (145 h.p. flat-six engine) and *Cessna 195* (300 h.p. radial) appeared on a brief visit.

There were also new models in the sky that were impossible to miss. Two gliders fitted with four and six SNECMA "Escopette" pulse jets respectively (22 lbs. = 10 kg thrust each) were demonstrated alternately in gliding and powered flight (take-off under own power), making as much noise as a multi-engined bomber. A new way to help private flying out of its present crisis? Let us hope this can be done without too much damage to the nerves of more earth-bound mortals!

Sud-Ouest SO 7060 "Deauville" sports three-seater; 103 h.p. engine; all-metal construction.



Fouga "Cyclope II" aerobatic trainer with Turboméca "Palas" of 330 lbs. (150 kg) thrust; behind, a Fieseler-Storch (MS 500) and a Fairchild C-82 "Packet."

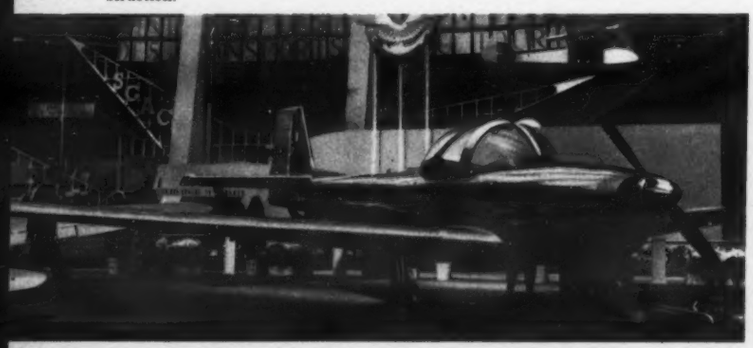


Six SNECMA "Escopette" pulse-jets with a total thrust of 130 lbs. (60 kg) provide take-off power for this glider; they can also be switched on during flight.

Fokker S.11 "Instructor" two-seater trainer; 187 h.p. engine.

The uncompleted prototype of the SIPA S.200 sports and training two-seater (all-metal construction) is to have a Turboméca "Palas" jet and retractable undercarriage; span 23 ft. 7½ in. (7.2 m).

Italy's latest two-seater trainer, the Piaggio P.148; 187 h.p. engine, all-metal construction.



HELICOPTERS

The most spectacular advances had been made in rotary-wing aircraft. Two years ago there was still nothing but more or less untried prototypes, but this year's salon had several well-tried production models to show.

During the Show a helicopter feeder service was run between the provisional "*Héliport de Paris*" (on the Esplanade des Invalides) and Le Bourget airport. Two *Hiller 360* three-seaters and a *Bell 47 D* trundled back and forth, on their 178 h.p. engines, over the heads of the Parisians, who had long since got used to seeing them. Demand for seats was high. Nevertheless it is doubtful whether any other large cities, less well-provided with parks and open spaces, would have dared to let single-engined helicopters operate right over their centres.

The most interesting and novel type in the Show was undoubtedly the three-seater *all-metal SO 1120 "Ariel III" jet helicopter* of the SNCA du Sud-Ouest, one prototype of which was on show in the Grand Palais and another at Le Bourget. A 275 h.p. Turboméca "Artouste" gas turbine drives a turbo compressor, which in turn feeds compressed air through the hollow blades of the three-bladed rotor to combustion nozzles at the blade tips, where fuel injection takes place. The noise produced in flight is considerable. Gross weight 2,645 lbs. (1200 kg); max. speed 112 m.p.h. (180 km/h); ceiling in oblique flight 11,810 ft. (3600 m); range (with 88 Imp. gals. = 400 litres kerosene) 155 to 186 miles (250 to 300 km). The rotor (diameter 35 ft. 5 in. = 10.8 m) rotates freely on roller bearings, so that no tail rotor is required to compensate for torque. A central rudder unit ensures directional stability and provides for changes of course in forward flight: at low speeds it is aided by lateral diversion of the gas turbine's exhaust flow.

Another machine of which there were two on show was the five-seater all-metal *Bristol 171 Mk.3* helicopter (Alvis "Leonides" engine of 550 h.p.; rotor diameter 48 ft. 6 in. = 14.8 m). It attracted a great number of spectators at the Grand Palais, particularly as a good view of the pilot's cockpit and controls could be had through the open door. Gross weight 5,200 lbs. (2360 kg); max. speed 140 m.p.h. (227 km/h); ceiling in oblique flight 19,000 ft. (5800 m); range 330 miles (530 km).

Apart from a still untried experimental machine by *J. Cantineau*, other helicopter types were to be seen only in model form. These included the well-known "fat Sikorsky" *S-55 of United Aircraft*, the projected twin-engined, twin-rotor *Bristol 173*, the *SE 3120* experimental three-seater of the SNCA du Sud-Est.—Finally mention should be made of the pleasant little collection of helicopter models from the *Musée de l'Air*, which provided a good historical survey.

JET POWER PLANTS, PISTON ENGINES, PROPELLERS

In the engine section of this year's Paris Show the main accent was unmistakably on jet power plants. The finest products of the French and British industries, some of the former being licence productions, were a delight to the engineer and made a deep impression even on the layman. On the other hand there were, of course, piston engines of all output classes, including the famous American four-row radial, the Pratt & Whitney "Wasp Major" and the no less successful two-row "Double Wasp," the British Bristol "Hercules" and "Centaurus" sleeve-valve engines, and a number of French, British and Italian medium and low-powered engines.

SNECMA's stand (Société Nationale d'Etude et de Construction de Moteurs d'Aviation, the French nationalized aircraft engine works) showed a cross section of the firm's extensive production programme, *e.g.* the *ATAR 101* jet engine—seven-stage axial compressor, annular combustion chamber with 20 combustion nozzles, single-stage turbine, "bullet"—was shown in several versions, such as the *101 B* for a thrust of 5,290 lbs. (2400 kg) and the *101 C* for 6,170 lbs. (2800 kg), and finally—with provision for compression cooling and afterburning—the *101F* for a max. thrust of 8,820 lbs. (4000 kg).—Fuel consumption of the *ATAR 101 B*, 1 lb. per lb. thrust per hour. The *TB 1000 A* propeller turbine—nine-stage axial compressor, six combustion chambers, two-stage turbine, reduction gear—now produces a take-off power of 1970 h.p. (with a dry weight of 990 lbs. = 450 kg). The well-known 14 cylinder two-row radial (formerly Gnome-Rhône) also continues in quantity production, in the *14X* version for 810 h.p. take-off power at

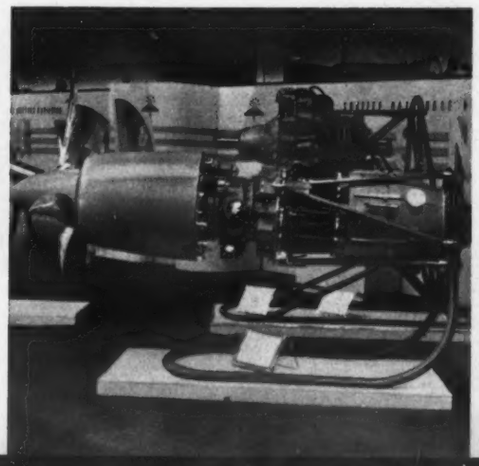
178 h.p. Bell 47D helicopter with four men on board, two of them on stretchers carried at the sides.

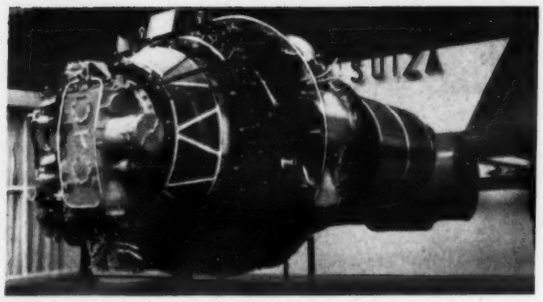
A 178 h.p. Hiller 360 three-seater helicopter takes off from the provisional "Héliport de Paris" on the Esplanade des Invalides.

The five-seater Bristol 171 Mk. 3 was shown both in the Grand Palais and at Le Bourget (550 h.p. engine ; all-metal construction). Next to the helicopter a model of the twin-rotor Bristol 173.

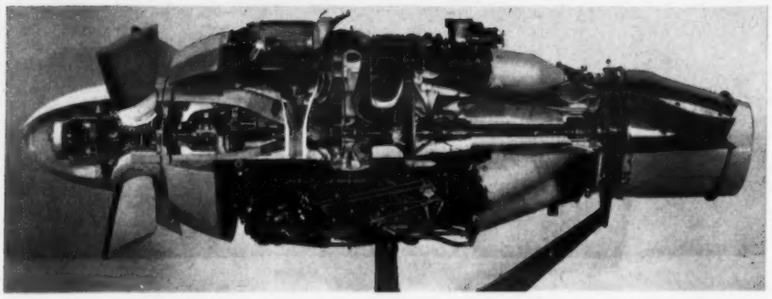
Particular interest was shown in the latest SO 1120 "Ariel III" jet helicopter (with 270 h.p. Turboméca compressor plant). It was also on show at both exhibition centres.

SNECMA's stand shows a cross section of the French government-owned engine works' extensive production programme. Left to right : model of the ATAR 101 F with afterburner (8800 lbs. = 4000 kg thrust) and electrical aircraft instrument group (Air Equipement generator ; Rotax starter) ; ATAR 101 test bench engine (after completion of a 15 hour run at 6170 lbs. = 2800 kg) ; ATAR 101 B (5290 lbs. = 2400 kg thrust) with petrol-electric equipment group (SNECMA-Labinal-Bronzavia) ; TB. 1000 A propeller turbine (1970 h.p. max. equivalent power) and 14 X two-row radial engine (810 h.p. take-off power).





Hispano Suiza showed the licence-built Rolls-Royce "Tay" (6250 lbs. = 2850 kg thrust) for the first time.



Rolls-Royce itself showed (in addition to the "Derwent" and the "Avon") a cut-away model of its "Dart" propeller turbine ; 1400 h.p. take-off output plus 300 lbs. (135 kg) residual thrust.

3100 r.p.m. A new design was the noisy "Escopette" pulse-jet auxiliary power plant, a 9.2 ft. (2.8 m) long "stove-pipe" of varying section with intake bent backwards. It contains no moving parts at all, weighs only 11.2 lbs. (5.1 kg) complete and gives a thrust of 7 to 22 lbs. (3 to 10 kg) according to fuel admitted. It is started by means of a spark plug, coil and battery.

Hispano-Suiza showed licence-built versions of the R.R. "*Nene*" (with afterburner) and R.R. "Tay." The former is to be fitted in the MD 450 "Ouragan" and is said to give a thrust of 5,070 lbs. (2300 kg) without afterburner, or 6,500 lbs. (2,950 kg) with. The latter has a static thrust of 6,280 lbs. (2,850 kg): fuel consumption 1.05 or 1.06 lbs. per lb. thrust per hour. The well-known *H.S. 12 Z* liquid-cooled twelve-cylinder Vee engine with direct fuel injection, for a take-off power of 1,280 h.p. at 2,650 r.p.m. (or 1,480 h.p. at 2,700 r.p.m.) was also exhibited.

Turboméca, the third French gas turbine firm, had a multitude of jet engines and turbines in the lower power class to offer*, *e.g.* "*Piméné*" (220 lbs. = 100 kg thrust), "*Palas*" (330 lbs. = 150 kg), "*Aspin I*" (485 lbs. = 220 kg), "*Marboré I*" (660 lbs. = 300 kg). "*Aspin II*" (730 lbs. = 330 kg), "*Marboré II*" (815 lbs. = 380 kg); also the "*Orédon*" (160 shaft h.p.) and "*Artouste*" (275 h.p.). Fuel consumption 0.6 to 1.1 lb. per lb. thrust per hour (according to speed of flight) in the "Aspin" double-flow engine; 1.00 to 1.12 lb/lb.h. in the other jets; 0.94 to 1.0 lbs./hp.h. (0.42 - 0.46 kg/hp.h.) in the turbines. Other products: air compressors ("Pimedon" and "Palouste"), turbo-ventilators, pumps, filters, cocks, valves, manometers, etc.

The *Arsénal de l'Aéronautique* showed a ramjet engine about 10 ft. (3 m) long for a thrust of 1,100 lbs. (500 kg) at 620 m.p.h. (1000 km/h); a target aircraft (reduced-scale copy of the German V-1 flying bomb) with intermittent ramjet engine and remote control; and finally a powerful, water-cooled H engine of 2,070 h.p.—*Potez* had air-cooled four, eight and twelve cylinder engines for take-off powers of 160 h.p., 200/220 h.p., 395/445 h.p. and 590/665 h.p.—and the efficient 240 h.p. 6 D-00 six cylinder in-line engine, now in quantity production at the newly-acquired Argenteuil plant, and demonstrated its light generator groups (D & H) for outputs of 1.5 to 18 h.p.—*Salmson* exhibited radial engines of 5, 7 and 9 cylinders for outputs of 60 to 200 h.p., as well as a recent development of the Argus AS 10 C (250 h.p.) and a new nine-cylinder helicopter engine of 175 h.p. with a weight of 360 lbs. (163 kg).—*Minié* and *Lutétia* showed air-cooled light engines of 35 to 80 h.p.

Among the foreign exhibitors particular mention should be made of the British engine firms: *Armstrong-Siddeley* with their super-powerful "Sapphire" axial compressor jet (7,200 lbs. = 3265 kg thrust) and the "Double Mamba" twin propeller turbine (2,540 h.p. plus 770 lbs. = 350 kg); *Bristol* with a cut-away model of the "Proteus" propeller turbine (3250 h.p. plus 790 lbs. = 360 kg) and its elegant "Hercules 763" and "Centaurus 661" sleeve-valve engines; *de Havilland* with their well-known "Ghost" jet engine (5000 lbs. = 2270 kg); *Rolls-Royce* with a cut-away model of the "Dart 3" propeller turbine (1400 h.p. plus 300 lbs. = 135 kg) and the "Avon" (6,500 lbs. = 2,950 kg static thrust) and "Derwent 5" (3,600 lbs. =1630 kg) jet engines; finally *Blackburn and General Aircraft* with the four-cylinder air-cooled "Bombardier" (180 h.p.), "Minor II" (100 h.p.) and "Major III" (155 h.p.).

The Italian engine industry was represented by *Alfa Romeo* with its eight-cylinder air-cooled 121 RC 22 Vee engine of 370 h.p. take-off power (and 225 h.p. six-cylinder 115ter). *United Aircraft* (Pratt & Whitney) had an impressive stand with a slow-running cut-away model of the "Wasp Major" (3500 h.p. plus) and a "Double Wasp" (2400 h.p.), the commercial airlines' standard engine. Take-off rockets ("JATO" and "JATO JUNIOR") by *Aerojet*, the leading American rocket firm, were shown, as well as the "Aerobee" experimental rocket.

Among the propellers, mention should be made of the well-tried three and four-bladed v.p. propellers of *Ratier*, with hydraulic and electrical operation, feathering, reversible pitch; also of Ratier's automatic "Heramatic" propeller for sports engines of 100 to 200 h.p. and the *Fiat 5006* propeller (Hamilton Standard licence) for 200 to 350 h.p. *Bréguet* acted as representatives for the British Rotol works, showing a cut-away model of an eight-bladed contra-rotating propeller; *Morane-Saulnier* showed a small two-bladed v.p. propeller.

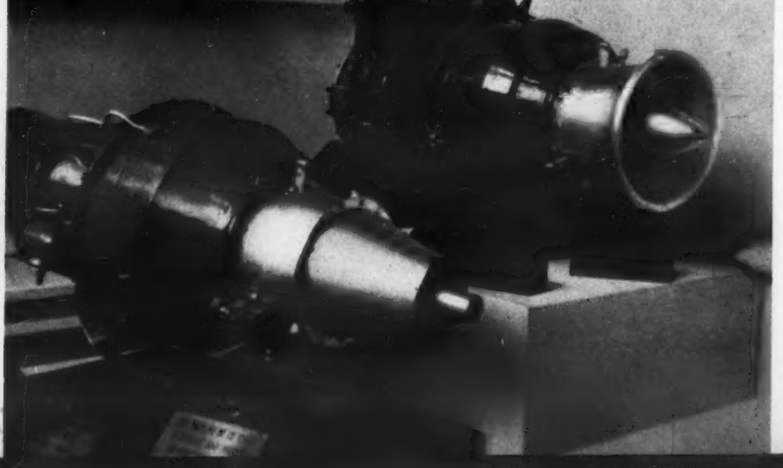
MATERIALS, ACCESSORIES, EQUIPMENT

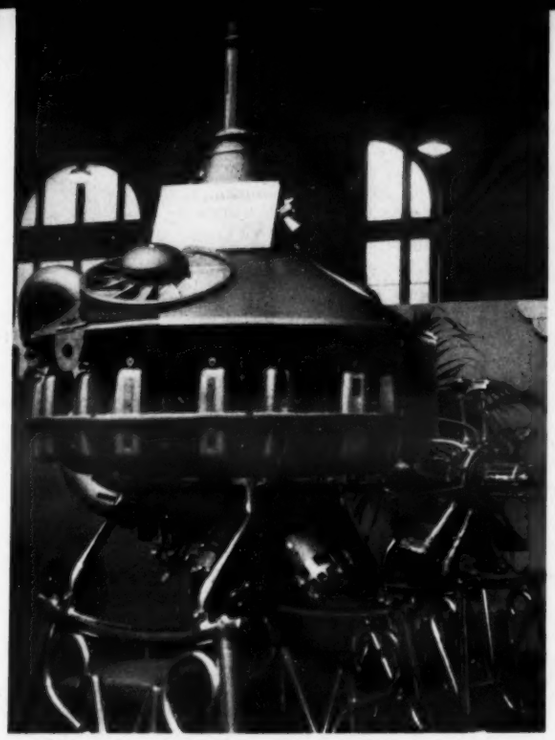
Any survey of accessories should, of course, begin with the display of structural materials which are so characteristic of modern aircraft construction. A whole book could be written on this subject! Suffice it therefore to mention three Paris firms which showed a multitude of semi-manufactured products: *Cegedur* (Cie. Générale du Duralumin et du Cuivre) showed rolled and forged parts of all kinds made from various aluminium alloys (duralumin, vedal, zicral, duralinox, etc.), the *Soc. Gén. du Magnesium* cast and pressed parts of magnesium alloys, and *Commentry Fourchamboult* stainless steels and nicral alloys for gas turbines. *Kléber-Colombes*, also of Paris, had a new ultra-light material on show, known as "Klégécell," 35 cu.ft. (1 m³) of which weighs 68 lbs. (31 kg). It is a kind of sponge plastic, non-inflammable, can be produced hard or soft and is used for thermal and acoustic insulation of aircraft cabins, production of "sandwich" structural parts, etc. *Alsthom* (Paris) showed perspex parts, including the 0.709 in. (18 mm) thick cockpit cover for the MD 450 "Ouragan." The only representative of the machine tool industry was *Etablissements Sciaky* (Paris), who exhibited their well-known electrical spot and seam welding machines for steel and light metals. The former are adjusted for a preliminary pressure of 4400 lbs. (2000 kg) and a welding pressure of 2200 lbs. (1000 kg), and can join together light metal parts of 0.14 in. (3.5 mm) each with a maximum current of 60,000 Amp. (300 KVA); the latter weld (max. 45.000 Amp. and 150 KVA)

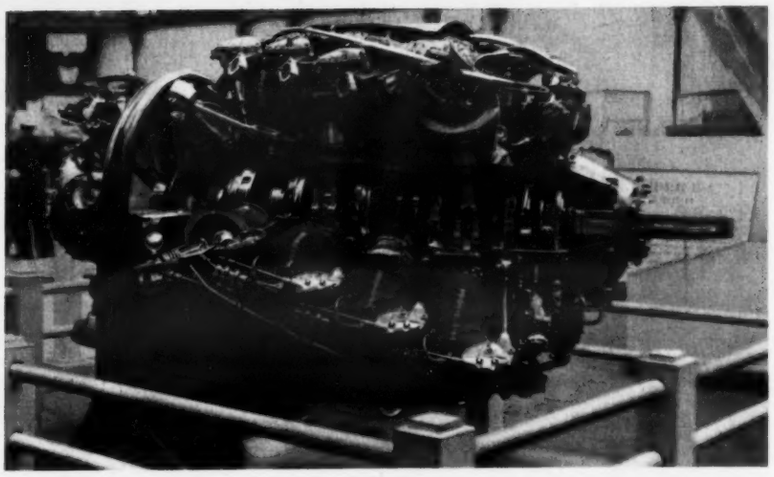
* The Continental Motors Corporation (USA) has recently acquired production rights for a number of Turboméca engines.

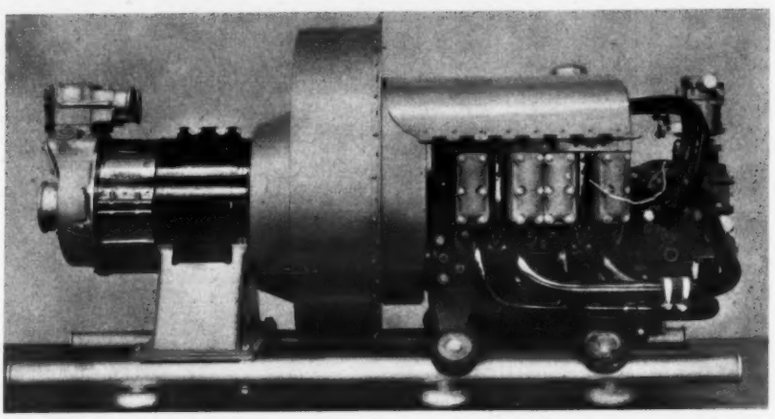
The Turboméca "Palas" already referred to several times (330 lbs. = 150 kg thrust) serves as take-off aid to a DC-3 ; increase in useful load for the same block distance: 1540 lbs (700 kg).

Turboméca also showed a number of other small turbojets. Photo shows the "Piméné" jet (220 lbs.= 100 kg thrust) and the "Artouste" turbine (270 h.p.), the power plant which drives the air compressor in the "Ariel III" jet helicopter.









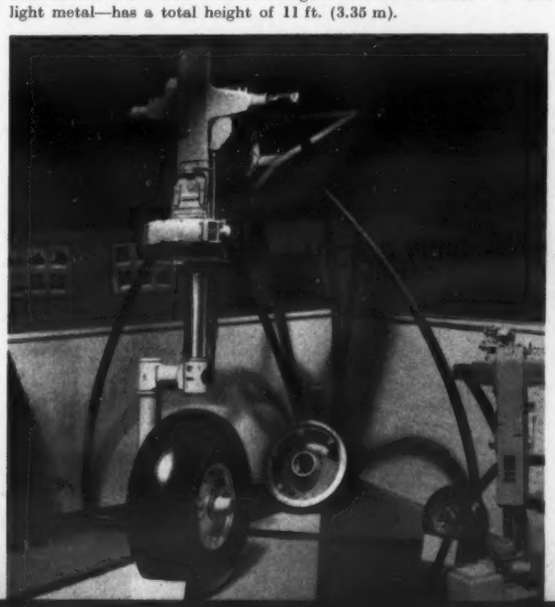
Piston engines will hold their own for a long time yet! Right, a full-size cut-away model of the most powerful aircraft engine in the world, the Pratt & Whitney "Wasp Major" (3500 h.p.); below, the Potez 4 H light generator group, a flat-four engine with generator for 5-10 KW and r.p.m. regulator. Left, the new Salmson 178 h.p. helicopter engine (for the SE 3120 helicopter), with a 89 h.p. 5 AQ 03 radial engine in the background.

aluminium alloy parts each 0.071 in. (1.8 mm) thick or steel parts up to 0.098 in. (2.5 mm) thick, in each case at a speed of up to 10 ft./min. (3 m/min.).

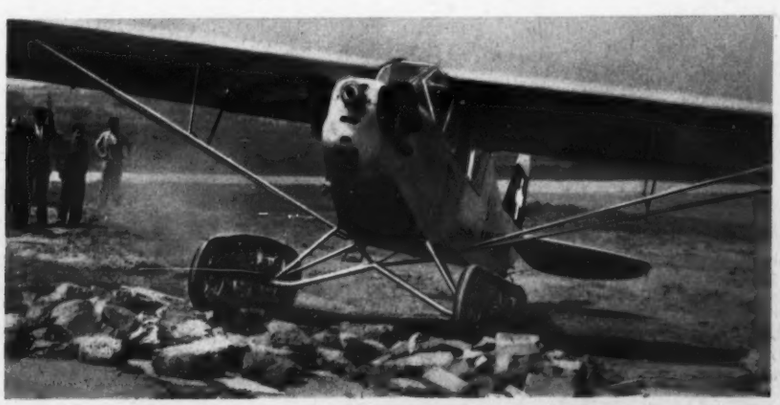
Messier (Montrouge, Seine) and *D.O.P.* (Boulogne, Seine), the leading French undercarriage manufacturers, showed landing gear of all sizes, perhaps the most striking of which were the gigantic sprung legs and wheels for the Bréguet 763 "Deux Ponts" (main undercarriage elements of welded steel, nosewheel of cast light metal). *British Messier* (Gloucester, England) showed a sprung landing gear for an unnamed British bomber, *Dowty* (Cheltenham, England) its liquid spring undercarriage for the Hawker "Sea Hawk," the "Meteor N.F.11" and Avro "Ashton." Alongside this there were a large number of hydraulic parts (accumulators, swash-plate pumps, distributors), modern brake pressure regulators (Messier) and a relatively small, three-stage air compressor for the extremely high working pressure of 3.090 psi (210 atü) (Messier), with the aid of which a number of hydraulic control systems can in future be converted to pneumatic operation. *Dunlop* (Paris), a firm which equips practically all French prototypes, showed tyres of all kinds, as well as wheels, brakes, control columns and aircraft windscreen wipers from its British sister company. *Kléber-Colombes* also exhibited tyres, including those of the "Constellation" which at present stand up to about 350 landings—and demonstrated pneumatic de-icers for wing leading edges and propellers. Mention should finally be made of Count Bonmartini's interesting eight-wheel track undercarriage produced by the *Etablissements Sciences Techniques* (Zurich-Rome), designed to make light aircraft of all kinds independent of aerodromes... provided the police don't object!

The large number of exhibitors of aircraft and engine accessories provided a striking proof that the French aviation industry has made tremendous progress in this direction during recent years and is today equal in many respects to the American and British equipment industries. *Bronzavia* (Courbevoie, Seine) showed engine accessories (fuel pumps, carburettors, injection pumps, filters, etc.), pneumatic and electrical equipment (suction pumps, compressors, DC motors for 24 V and up to 160 W) and the cabin compressor for the SE 2010 "Armagnac" (centrifugal compressor) and SO 30 P "Bretagne" (piston compressor), automatic cabin pressure regulators for fighters, bomb sights and camera guns for military aircraft and finally VHF air-borne radio equipment in the international class. *Air Equipement* (Asnières, Seine) showed licence-built Bendix instruments (*e.g.* automatic radio compasses) and equipment of their own design (fuel regulators for gas turbines, generators, air compressors, starter motors, electro-mechanical controls, etc.); *AMA* (Levallois-Perret, Seine) pneumatic and electrical engine control

This Messier nose wheel from the Bréguet 763 "Deux Ponts"—of cast light metal—has a total height of 11 ft. (3.35 m).



Count Bonmartini's caterpillar undercarriage on a Piper "Cub" taking an obstacle.



instruments, Vokes filters, heat exchangers, and parts for pressurization systems. *Faure-Herman* (Boulogne-sur-Seine) showed fuel consumption gauges for piston and turbo engines, electrical r.p.m. counters and test bench equipment; *Ragonot* (Malakoff, Seine) generators, electric motors and transformers for aircraft electrical networks, and remote transmission systems; *Rellumit* (La Garenne-Colombe, Seine) micrometric filters for fuel and lubricants, automatic metering instruments and pumps for fuel trucks (106 to 1,413 cu.ft./h. = 3 to 40 m³/h); *Aviac* (Courbevoie, Seine) electrical and mechanical remote control systems for aircraft; *ABG* (Paris) magnetos, spark plugs and interference suppressors; *Jacottet* (Courbevoie, Seine) remote control and the hydraulic power-boosting system for the SO 6021 "Espadon" jet fighter's controls.

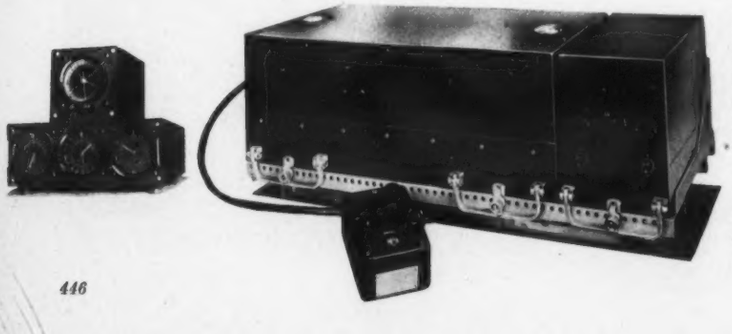
Representative of the instrument makers are the *Société Delord* (Paris) which makes high-precision engine control instruments for piston-engines and gas turbines, namely pyrometers for the exhaust temperature and fuel consumption gauges, as well as a multitude of measuring instruments and test bench equipment, and the *Etablissements Jaeger* (Levallois-Perret, Seine) which produce electrical r.p.m. counters and altimeters (up to 65,620 ft. = 20,000 m). The *Société Française d'Equipements pour la Navigation Aérienne* (SFENA, Neuilly-sur-Seine), well-known as producers of gyroscopes, automatic pilots, radio-sondes, and VHF radio equipment, aroused considerable interest with two special instruments, an automatic position indicator and a non-oscillating distant-reading compass. The former, connected with a gyroscopic compass and clock, is switched on at a specific point—during night fighting or at the beginning of a blind turn—and shows the pilot his position in relation to his initial position, by means of an aircraft silhouette which moves about behind a transparent reference grid. The second instrument, a very small master compass only 4.7 in. (12 cm) in diameter, will doubtless be a serious rival, once it is ready for production in quantity, to the American Fluxgate and Fluxvalve compass systems. It consists of two swivel-mounted bar magnets which actuate an oblique disc in a fixed coil system. The latter serves for the remote transmission of the relative setting of the magnet rods, whose oscillations are damped by Foucault currents—due to movement of the magnets between copper plates.

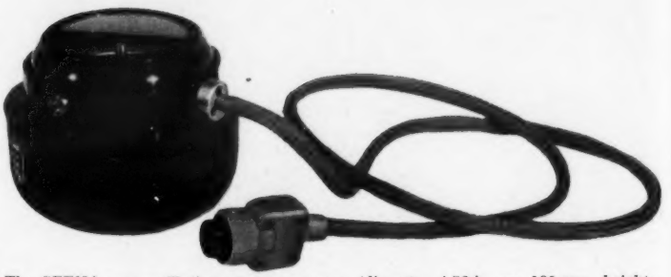
Among the foreign accessories exhibitors mention should be made above all of the *Bendix International Division* of Bendix Aviation Corp. (New York), which showed not only radio and navigation instruments (*e.g.* the NA-3 VOR receiver and others) but also fuel flow totalizing instruments for single and multi-engined aircraft, ignition systems, oscilloscopes, fuel metering equipment for jet engines and propeller turbines, etc. *Dowty* (Cheltenham, England) also showed metering equipment, and the *Fabbrica Italiana Magneti Marelli* (Milan) was represented by generators, electric motors, magnetos, plugs, switches, etc. The *Sperry Corp.* (New York), represented by Appareillage Aéronautique, showed its well-known Zero Reader.

Producers of special equipment in France include the two parachute firms *Aviorex* (Clichy, Seine) and *Aerazur* (Paris). The latter also builds life-jackets, rubber dinghies, rescue floats and ejector seat equipment and has interesting ground equipment, such as road trailers with expanding sides (to double the useful area) and bogie-type chassis (for very close turns), as well as pneumatic hoists for damaged aircraft. The *Société Française d'Optique et de Mécanique* (Rueil-Malmaison, Seine) showed air cameras (including their latest type for small pictures—4.9×4.9 in. = 125×125 mm), lenses, enlargers for rapid interpretation of air photographs (165 ft. = 50 m in 8 minutes with enlargement up to 9×9 in. = 230×230 mm) and a number of enormous enlargements of razor-sharp bird's eye views of the centre of Paris. The only armament to be seen was on the French Admiralty's stand, namely an aircraft torpedo with delta wings which, released from a height of 13,120 ft. (4000 m) can glide over a distance of 10 miles (15,000 m), and loses its wings on hitting the water; and a rotating turret equipped with two MG 151/20s.—Finally a word about the *Agence Legastellois*, which has specialized in buying and selling aircraft and equipment of all kinds.

In the radio field there was a great deal of interesting new development. The French industry alone, grouped together under the *Fédération Nationale des Syndicats des Industries Radioélectriques et Electroniques* (SNIR), was represented by twelve instrument firms, six valve firms and five accessories firms. Then there were the foreign exhibitors: *Bendix International* (New York), *Standard, Radio Division* (London) and *Brown-Boveri* (Baden, Switzerland), the latter represented by the Paris company Electro-Mécanique.

Decca Navigator built by the Société Française Radioélectrique (SFR-Decca 501); receiver and indicator, without Flight Log.





The SFENA non-oscillating master compass (diameter 4.72 in. = 120 mm, height 3.15 in. = 80 mm) is connected via a single-valve amplifier (not shown here) to a repeater compass and/or directional gyroscope.

And now for details: the *Laboratoire Central de Télécommunications* (LCT, Paris) showed in particular its distance measuring equipment for short distance navigation, which is used in conjunction with the omnirange. The air-borne transmitters work in the 30 cm band (1000 m/cs), the fixed repeater beacons on a half wave-length. By means of a cleverly contrived key (different for each air-borne transmitter) up to 50 calls can be dealt with simultaneously by a single ground station; range 200 nautical miles. *Le Matériel Téléphonique* (LMT, Boulogne-Billancourt, Seine) showed quartz-controlled VHF R/T equipment for three channels (24 V electrical network or batteries), weighing 13.7 lbs. (6.20 kg) or 18.7 lbs. (8.50 kg), and automatic VHF R/T D/F instruments, as well as minute piezo-electric quartzes, and demonstrated a blind flying trainer of its own design with "recording aircraft model" (over a large glass-covered practice map) in which the pilot also receives the radio aid signals in his headphones. The *Société Française Radioélectrique* (SFR Paris) showed a radio altimeter for frequency modulation and another for keying, also an ILS receiver, a radio compass (Marconi licence) and a high precision LF Decca aircraft set (SFR-Decca 501), with the usual "red," "violet" and "green" indicators and the new "Flight Log" which marks the aircraft's position on a special map.[1] *Radio-Industrie* (Paris) demonstrated automatic DME repeater beacons (UHF and VHF), aircraft radar aerials (VHF and SHF) and aircraft pulse instruments (VHF) with cathode ray tube for distance measuring and homing on five channels, and the *Compagnie Générale de T.S.F.* (Paris) showed its UHF blind approach equipment type ASV 23, and HF receivers and microphones.

Finally mention should be made of the full-size 3 cm GCA station whose PAR and SRE aerials and scopes were to be seen on the stand of the Compagnie Française Thomson Houston (Gennevilliers, Seine) and which are today to be found at Melsbroeck, Le Bourget, Malpensa, Schiphol, and Copenhagen airports, etc., VHF and HF R/T (and W/T) equipment for the tropics, and VHF signalling beacons of the *Société Industrielle des Procédés Loth* (Paris) and the radio-teleprinter and VHF R/T equipment of *Soparel* (Paris).

One of the most interesting novelties in the realm of flight safeguarding was the model shown by the British *Standard Telephones & Cables* (London) of the automatic *VHF R/T position plotting equipment*, which will probably shortly be installed in the Brussels flight information region. It connects three separate automatic VHF R/T D/F stations (with Adcock aerials and cathode ray tube), such as are already in use at a number of aerodromes, on a specific frequency and via telephone cables to a luminous map in the flight information centre. If a pilot, *e.g.* of a sports aircraft which is only equipped with a VHF radio set, calls the FIC on the specified frequency, the official, while still talking to the pilot, sees the latter's exact position at the point of intersection of three lines of light on the map. He therefore knows where his caller is, can give him his position and direct him as required. In the case of Belgium the FIC would be at Melsbroeck and the three R/T D/F stations at Ostende, Antwerp and Charleroi.

GALA AIR DISPLAY AT LE BOURGET

July 1st, 1951: On this perfect summer Sunday all Paris flocked from an early hour by car, train, bus, cycle or even on foot, to the flag-bedecked airport of Le Bourget. The crowd lined up on either side of the north-south runway and waited, whiling away the time with gallons of Coca-Cola. Shortly before three *Vincent Auriol*, President of the French Republic, accompanied by members of the Government, diplomats, military officers and industrialists, entered the stand of honour on the central terrace of the main building.

Then it started—and everything went off like clockwork.—Two gliders with SNECMA pulse-jets roared twisting and turning over the field, and the Aubert "Cigale Major" and Fokker S.11 "Instructor," the Morane-Saulnier M.S. 733 and SIPA S.12, the elegant jet-powered Fouga "Cyclope I" and "II," and finally the Rey 01 (with shock-absorbing wings), Macchi M.B. 320 ("Vema 51"), Morane-Saulnier M.S. 703 and Fokker S.13 "Universal Trainer" were put through their paces.

[1] To supplement the two existing Decca chains in Jutland and South East England, a new chain was opened in North West England in mid-June, 1951; the South West England chain should be ready by the end of July, 1951, a German chain is under construction and it has been decided to build a chain in France.

Any moment now! Bréguet "Deux Ponts," Sud-Est "Armagnac" and Paris police in readiness.

Three SO 30 P "Bretagnes" in formation flight, each with one engine idling.

Gerben Sonderman, Fokker's chief pilot, created a great sensation with a new kind of "Dutch roll," when he pulled his 190 h.p. "Instructor" straight up from the concrete runway into a fast climbing roll. Very daring—but perfectly executed. Not to be recommended, however, to the beginner!

Next came the heavy-weights, beginning with the Nord 2501 "Noratlas," the French counterpart of the "Packet." This was followed by the Martin B-26 "Marauder" "flying test bench," with screaming jet and stationary propellers. Three SO 30 P "Bretagnes" demonstrated single-engined flight in formation; and finally the two Bréguet 763 "Deux Ponts," enveloped in clouds of dust, taxied up to the take-off point, roared down the runway, took off and moved away, to give place to the two SE 2010 "Armagnacs" which were following close behind. For a time the sky over Le Bourget was full of giant aircraft, especially when a few minutes after the two "Deux Ponts" and the "Bretagnes" had landed (the "Armagnacs" flew on to their home base) eleven Boeing B-50s of the USAF thundered over the airport, followed by three Convair B-36 intercontinental bombers.

Entr'acte: Chief pilot Goujon of the SNCA du Sud-Ouest demonstrated the experimental "SO 30 Nene," and his colleague Dellys the spluttering, whirring SO 1120 "Ariel III" jet helicopter.

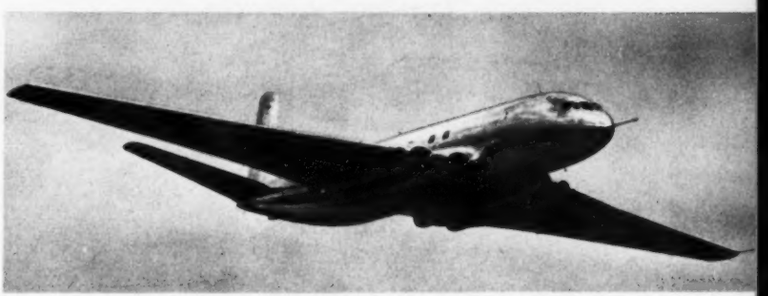
Next came the turn of the fighters. Two teams from the French Air Force opened the high-speed circus with aerobatic performances of breath-taking precision, the team of nine arousing particular admiration. The whole team moved as one. During the final figures the smoke generators were switched on. A long climb... and suddenly the formation sprayed out in all directions like a giant firework.

Now for the individual displays. The SO 6021 "Espadon" swept-wing fighter piloted by M. Guignard, showed off its elegant lines and impressive performance. Jacques Lecarme, who is well-known to *Interavia* readers, showed himself as versatile at the controls of a "Nene-Vampire" (Mistral) of the SNCA du Sud-Est as with the pen. He demonstrated above all precision rolls with the aircraft turning through 90° at a time. He was followed by Colonel Rozanoff in the new French swept-wing fighter, Dassault MD 452 "Mystère," an astonishingly manoeuvrable aircraft despite its high speed (over 633 m.p.h.).

After a brief interlude by the "helicopter ballet" it was the turn of the French Naval air units.—Eight Curtiss "Helldivers" and thirteen Curtiss "Hellcats" gave a display of "strafing." Four "Helldivers" showed in a small space at the end of the runway how landings (and take-offs) take place on board an aircraft carrier, folding their wings while still taxying.—Forty-five parachutists jumped out of Ju 52 transports and collected up supplies also dropped by parachute. Twin-engined SO 95 trainers and land-based patrol aircraft of the well-known Bloch (Dassault) 175 type appeared in the sky, followed by Bréguet 731 reconnaissance flying boats and Nord 1402 amphibians.

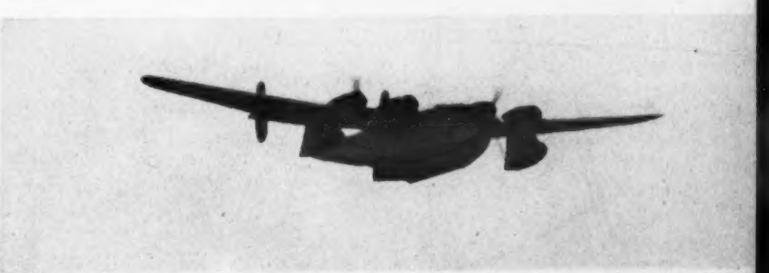
The last 65 minutes of the display were devoted to foreign participants.—John Derry demonstrated the new British de Havilland "Venom" jet night fighter with complete mastery. Lt. Dick, of the Royal Navy, followed with the Vickers-Armstrongs "Attacker" carrier-borne jet fighter, and Flt.Lt.Else showed what the "Meteor NF 11" night fighter (version developed by Armstrong Whitworth) is capable of. The greatest impression, however, was made by the English Electric "Canberra" twin-jet bomber. Admittedly, it was not shown at anything like its full gross weight of 44,000 lbs. but it got off the ground in ten seconds and carried out rolls and loops like the most manoeuvrable of fighters.

Meanwhile the British de Havilland "Comet" (four D.H. "Ghosts"), Vickers-Armstrongs "Viscount" (four R.R. "Dart" propeller turbines) and Bristol "Brabazon" (eight Bristol "Centaurus") and a team of twelve American McDonnell



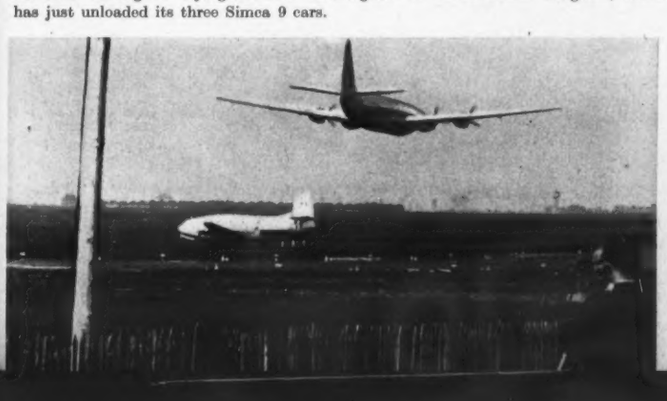
The de Havilland "Comet" showed off its elegant lines at high and low speed.

The Bristol 167 "Brabazon," the biggest aircraft in the world and the "pride of Great Britain"; below a Republic F-84E "Thunderjet" of the USAF "Skyblazer Team" taking off.



A Bréguet 731 long-range flying boat of the French Naval air service greeting its land-based stable-mates.

SE 2010 "Armagnac" flying low over the Bréguet 763 "Deux Ponts" freighter, which has just unloaded its three Simca 9 cars.

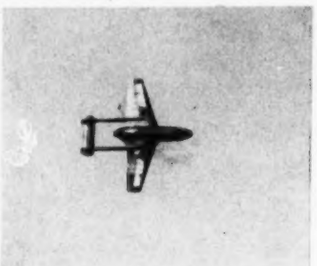


The Vickers 700 "Viscount" four-engined propeller turbine commercial transport (Rolls-Royce "Dart," also gave a brief but impressive demonstration.

Dassault MD 452 "Mystère" single-seater, demonstrated by Colonel Rozanoff.

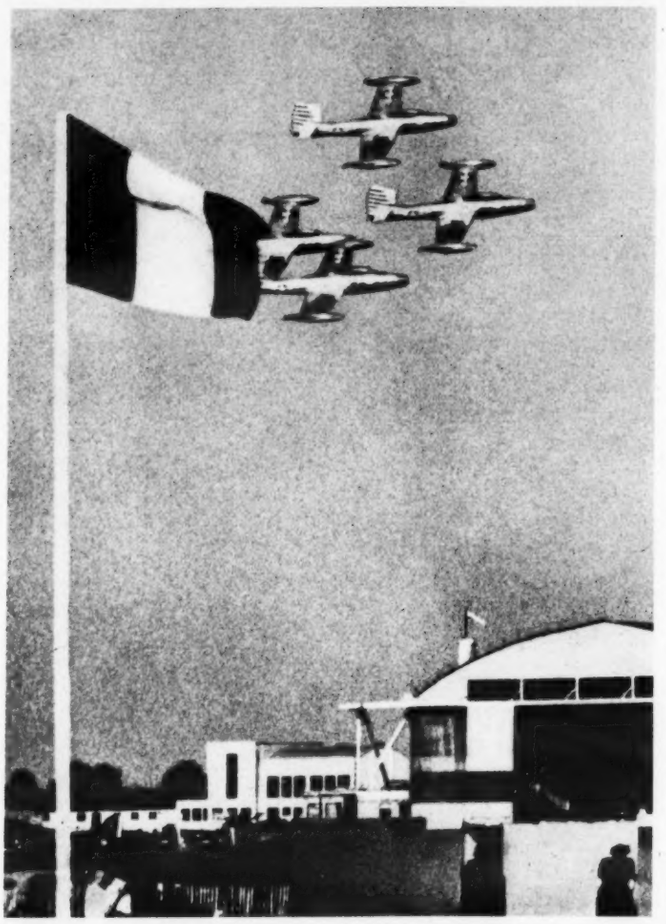
Sud-Ouest SO 6021 "Espadon" fighter flown by M. Guignard.

English Electric "Canberra B.Mk. 2" jet bomber ; full aerobatic programme, pilot Mr. Squire.



De Havilland "Venom" two-seater night fighter, piloted by Mr. Derry.

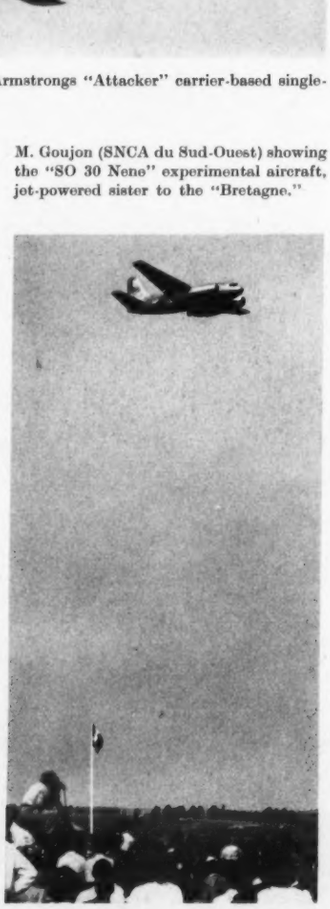
Lt. Dick, Royal Navy, puts the Vickers-Armstrongs "Attacker" carrier-based single-seater fighter through its paces.



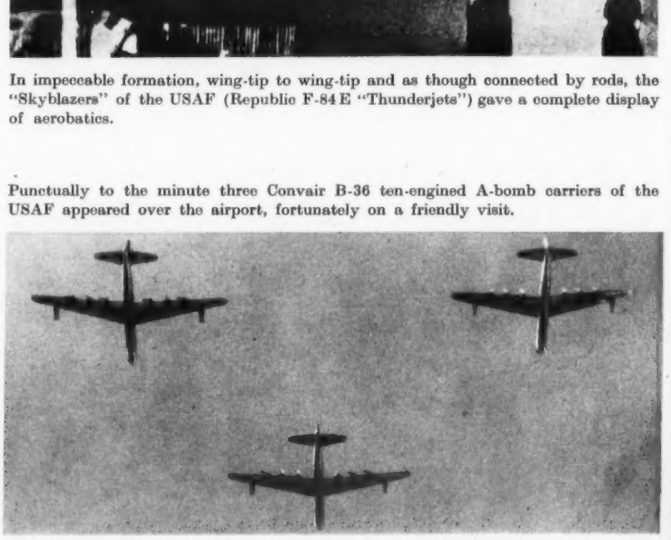
In impeccable formation, wing-tip to wing-tip and as though connected by rods, the "Skyblazers" of the USAF (Republic F-84 E "Thunderjets") gave a complete display of aerobatics.

Loops, rolls, inverted climbs at very low heights demonstrated by the A. W. "Meteor N.F.11" two-seater night fighter, flown by Lt. Else.

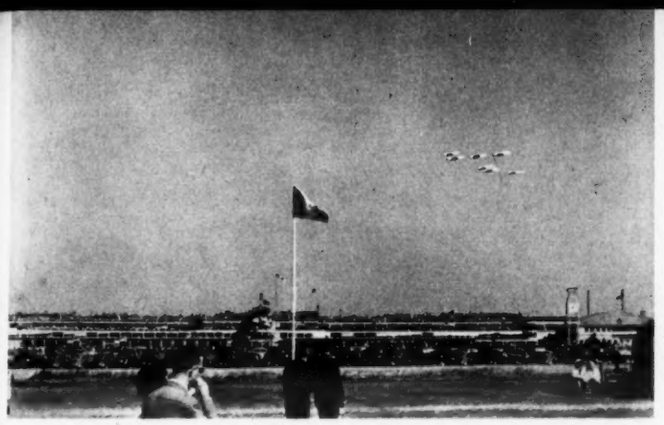
M. Goujon (SNCA du Sud-Ouest) showing the "SO 30 Nene" experimental aircraft, jet-powered sister to the "Bretagne."



Punctually to the minute three Convair B-36 ten-engined A-bomb carriers of the USAF appeared over the airport, fortunately on a friendly visit.



Bloch-Dassault 175 land-based patrol aircraft of the French Naval air service.



A "Vampire" squadron of the French Air Force flying over the President of the Republic's stand and the packed terraces of the airport building.

Precision rolls in formation, and at the end a "firework show" of smoke trails, were demonstrated by a squadron of the French Air Force.

"Banshee" jet fighters flew non-stop across the field. The latter had taken off from the aircraft carrier USS "Coral Sea" in the Mediterranean between La Spezia and Marseilles, appeared punctually to the second over Paris and returned to their flat-top 500 miles away.

Two teams of four from No. 74 Squadron, RAF Fighter Command ("Tiger Squadron") and the "Skyblazers" of the USAF formed the climax of the Show. The British flew Gloster "Meteor 8s," the Americans Republic F-84 E "Thunderjets," both with the utmost bravura. The "Thunderjets" showed continuous rolls, loops, turns and climbs at breath-taking speed and in very close formation, completing their display by diving to the airfield from four directions and breaking away one above the other with split-second precision.

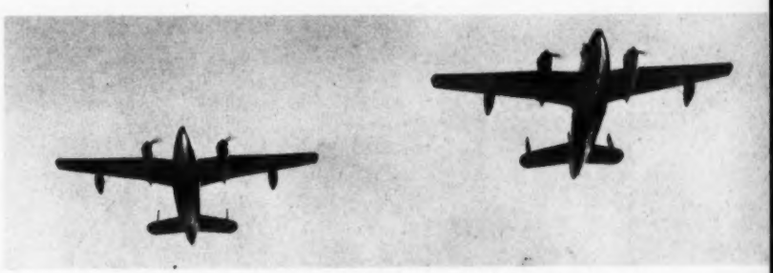
The final event was a fly-past: 48 "Vampires" from the French Air Force, 48 "Vampires" of the RAF, 48 "Thunderjets" of the USAF. The "Skyblazers" evidently got in the way of the French, who broke away in all directions. For a few moments the sky was full of aircraft and there was many a fast-beating heart among the spectators. The incident, however, passed off without harm. The British and Americans flew past in exemplary order.

*

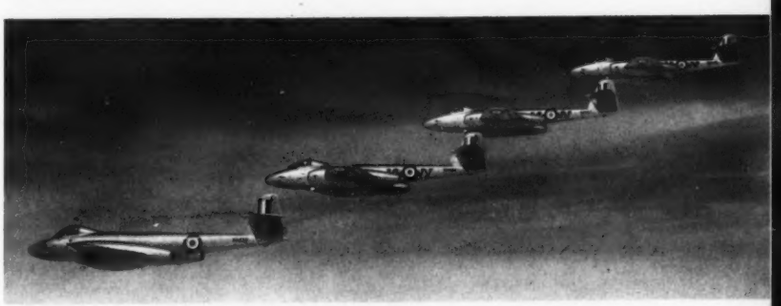
What impressions did the visitor bring away from the aviation fortnight, which passed by so quickly?

The most persistent will certainly be of the quality of the newer commercial and personal aircraft, the efficiency of the jet fighters, night fighters and bombers and of the engines, whether jet or reciprocating, and equipment which constantly increase their speed and reliability. One thing was clearly proved; that the French industry has now drawn level in all fields of aviation and is once again in a position to export.

First European appearance of a squadron of twelve McDonnell "Banshee" carrier-based fighters from the aircraft carrier "USS Coral Sea." The squadron took off from its flat-top in the Mediterranean, appeared over Paris at the precise minute and returned to its floating base.



Nord 1402 amphibian of the Aéronautique Navale, for sea rescue service and anti-submarine operations.



Four Gloster "Meteor 8s" of No. 74 Squadron, RAF Fighter Command, gave an exhibition of precision aerobatics.

COCKTAIL

The *Salon* is dead — Long live the *Salon* !

The classic formula used to announce the death of a sovereign and proclaim his successor can well be adapted to the Paris Aircraft Show. After all, why not?

Whatever changes the rigours of the times, the increasing bulk of aircraft and the complicated nature of technical developments may bring to this unique international air show, it will surely continue in existence. How could anyone seriously think of doing away with a function which—quite apart from its official purpose—provides an excellent excuse for visiting Paris, meeting friends from all over the world—and taking a "cure" of cocktails for one's gout or one's liver!

*

For the aviation fortnight in Paris—which of course lasted 17 days—was also the cocktail fortnight. Manufacturers, government officials, air transport companies, all vied with each other in the invitations they sent out. We hurried from the Plaza to the George V and from the George V to Latin America House. Conversations that had begun at the Pavillon Royal were continued at the Aero Club and appointments were made to finish them at the Grand Palais or Le Bourget. After all, we had to go and have an occasional look at the aircraft!

*

And then, of course, there was plenty to drink inside the Show. And I don't mean just at the bar. With their traditional shyness, the British had concealed private bars behind their jets and models.

For those who preferred Bourbon to Scotch, United Aircraft had unlimited treasures, while Fokkers provided their national gin, and the SNCASO, Dunlop, SNCASE and Kléber-Colombes vied with each other in offering vintage champagne cooled to perfection.

Pity the USSR did not exhibit: I am very partial to vodka with caviar...

*

Another notable absence was that of M. Maroselli, the French Air Minister, who—in the midst of the election campaign—was to have flown from Luxeuil to Paris in the morning.

However, the weather was impossible and the flight therefore had to be cancelled. Treacherous element!

*

Ministers, ambassadors, admirals, generals, air attachés... the French President's suite was so brilliant that I was seized with the very natural ambition to have my meeting with him recorded for posterity.

I therefore treacherously asked two of my friends who "operated" for the newsreels to ambush themselves nearby...

Alas! The President was so deeply engaged in conversation with his son Paul and with Colonel Cressaty that he didn't see me until he had gone some ten yards beyond the Interavia stand.

So you will never see pictures of the historic hand-shake or the presentation to the President of the French Republic of our special Aircraft Show issue.

*

"In the summer it rains indoors" said Daniel Rastel, SNCASO chief pilot, wittily.

If there had been only rain! But on Thursday there were the kids...

They had been admitted free, and the result was excellent publicity for aviation but disastrous propaganda for large families.

These dear little angels gave full rein to their imaginations. Some of them tried to climb into the Fokker, others to take down the "Escopette" and play soldiers with it! Others again, more well-behaved, contented themselves with picking the hydrangeas to give to their mothers, or playing swings on the blades of SNCASO's helicopter.

Enough to put you off children for the rest of your life. If my son were not already six years old, I certainly wouldn't wish to be a father!

*

Yes, there were the kids—But there were also the "ladies." Particularly those who had been dragged along to the Show by their husbands and who took

SALON

their revenge by never letting them stop to look at anything they found interesting.

There was one in particular who, arriving at the SNECMA stand where the ATAR which had just run 15 hours at a thrust of 6200 lbs. was on show, made this delightful remark: "I can't imagine why they want to show that old thing! I think the blue and yellow ones where you can see the insides are much prettier."

Having sworn never to have any children, one felt like taking a vow of celibacy too!

*

To provide a restful change from the Grand Palais there was the Show at Le Bourget. With Elisabeth Boselli taking her sun-bath between flights—and between showers—with the cavortings of the "Ariel," the sale of tropical fruits (picked the same morning), brought in by U.A.T. aircraft, and flowers from Nice flown up in two hours by aircraft of Air France. And the magnificent Toulouse dialect of the "Armagnac" mechanics!

True, the President did not come to Le Bourget—except on July 1st—but as compensation there was a visit from Prince Bernhard of the Netherlands, who showed a connoisseur's—and a possible purchaser's—interest in the aircraft.

For example he asked a good many questions about Paul Aubert's touring aircraft.

"If you like," said the designer who was unaware of the identity of his illustrious visitor, "I can send you some literature on it. Just give me your address in Holland"...

*

English may be the chosen language for the control tower, but it is only one language among a hundred in the Tower of... Babel. It was there and not at Latin America House that OFEMA should have held its cocktail party. Representatives from all over the world met there and "man speak italiano" (!) was *de rigueur*.

Out of courtesy the guests spoke French. It was in this language that Mr. Correa of Bendix International greeted his namesake Major Correa of Transportes Aereos Portugueses. And it was also in French that President Grimault and Daniel Moral played the "daughters of the house."

Too bad for those who did not understand! They should ask ICAO to introduce the Q code for "Quoquetails."

*

Everything comes in time, even the end of a Show. And contrary to all forecasts—except those of Monsieur Héreil—the weather was superb on July 1st. The Le Bourget display was a triumph.

We used to talk about Hitler's weather, but in future it will Héreil's weather.

*

Everything about the display was so perfect that I shouldn't have known what to say if the announcer had not occasionally consented to depart from the text with which the Union Syndicale des Industries Aéronautiques (Association of the French Aircraft Industry) had prudently provided him.

It was thus that I was able to salute in passing the Dassault "852", Armagnacs made by the SNCA du Sud-Ouest, the "B 18" and "B 24," ancestors of the "B 50 Fortresses"...

I will pass over the other similar gems... What matter? The onlookers, experts for the most part, made their own corrections.

*

The lamps are out, the aircraft gone, the stands empty. Yet in front of Police headquarters there still stands a Bell helicopter, waiting sadly, like a dog who has lost his master...

Charles de Levis Mirepoix told me: "During the past fortnight she has made a hundred trips between the Invalides and Le Bourget, and now I am waiting for permission to fly her to Brétigny!"

It was still there the next day...

If you didn't get to the Air Show you may still have a chance to see it—it may be there still.

Georges Février

Book Reviews

Modern Aircraft Design, by J. L. Nayler, M.A.— Published by Temple Press, London, 1950.

"Much of aircraft design is still an art, but the proportion of science behind it steadily increases with time, whether it deals with supersonic aircraft on the one hand or helicopters on the other." Following this principle, the author who, as secretary of the British Aeronautical Research Council, is especially qualified to deal with the subject, gives a technically sound but readily understandable outline (without mathematical complications), compressed into 118 pages, of the tremendous background of knowledge and experience which lies behind modern aircraft design. Above all it shows how the threefold problem of speed, lightness and strength is tackled and solved on the drawing board, in the laboratory and in flight tests. A good deal of space is also given to the so-called "impedimenta," such as undercarriage, pressurization equipment, passenger amenities, deicing, instrumentation, radio and radar. J. L. Nayler's book is designed primarily to provide an introduction into the technicalities of aircraft design for engineers and technicians in allied industries. At the same time, however, it gives even the initiated a useful general survey. Since the book is published in the Technical Trends Series, special attention has been given to the latest advances, for example in supersonic flight, helicopters and jet transport aircraft. The text is supplemented by 23 selected photographs and 4 diagrams, and an index is provided (English). *Ri.*

Foundations of Aerodynamics, by A. M. Kuethe and J. D. Schetzer. Published by John Wiley & Sons, New York, 1950.

This textbook on the principles of aerodynamics by two professors of the University of Michigan (Department of Aeronautical Engineering) is written for the advanced student of aeronautical engineering and requires considerable basic knowledge of mathematics and physics. The book deals first with the well-known theories of perfect two and three-dimensional flow round thin airfoils, then with those of compressibility and finally with the behaviour of viscous and viscous compressible fluids, including boundary layer problems. (363 pages; many illustrations, tables, diagrams; problems; index; English.) *Ri.*

Aérodynamique expérimentale (second edition), by Pierre Rebuffet. Published by Librairie Polytechnique Ch. Béranger, Paris & Liège, 1950.

In this textbook Pierre Rebuffet of the French Office National d'Etudes et de Recherches Aéronautiques, gives the substance of his lectures at the Ecole Nationale Supérieure de l'Aéronautique on the properties of fluids. This second edition has been considerably enlarged, and greater space has been given to the mathematical bases of experimental aerodynamics. Purely empirical formulae have not been included, however, since the engineer is expected to acquaint himself with these in his practical work. The symbols and definitions used are those which have been internationally accepted. As the book contains nearly 800 pages it is impossible to do more here than give the headings of the nine main chapters: 1) General remarks on the mechanics of fluids, 2) General phenomena and principles, 3) Wind tunnels, 4) Measuring and observation equipment, 5) Simple bodies, 6) Wings, 7) Propellers, 8) Aircraft and 9) Rotary-wing aircraft. An appendix contains Busemann shock diagrams, a Tesson diagram, references to French and foreign papers on wind tunnels, a list of classic and laminar NACA profiles and their characteristics. This book, with its 660 illustrations and 45 tables will be invaluable to both student and practical engineer on all problems of aerodynamics. (French.) *Rh.*

Comment apprendre à piloter un hélicoptère, by G. Busson and P. Lefort. — Chiron, Paris, 1951.

This little manual gives a *résumé*, in clear, concise form, with numerous illustrations, of everything a prospective helicopter pilot needs to know. The first four chapters are devoted to a study of the aerodynamic forces affecting the flight of rotary-wing aircraft, and to a description of present-day helicopters and their controls. The fifth chapter compares a classic aircraft with a helicopter from the pilot's point of view, and the sixth contains information on training, certificates, licences, etc. (the rules for helicopters have not yet been internationally recognized but the authors propose to bring this chapter up to date as progress is made in this direction). (French.) *Rh.*

Le pilotage des avions classiques et à réaction, by Captain F. Lamy. — Charles-Lavauzelle & C^{ie}, Paris, Limoges, Nancy, 1951.

"It is relatively easy to fly a modern aircraft. Present-day flying equipment, being technically reliable, makes few fundamental demands. However, if the aircraft is to give the best possible performance and be flown successfully at all times and in all weathers, it is soon found that flying demands very extensive knowledge." These opening sentences of Captain Lamy's new book define in a few lines the object of the book, which is to describe in clear and simple, but comprehensive form, the elements of the art of flying. This "flying course" covers all aspects of the subject—personnel, equipment, elements of flight, various different manœuvres etc.—according to a methodical plan and with a great deal of common sense. One surprising point is the number of apparently insignificant "details" cited by the author—but is not "good flying" made up precisely of the observance of a quantity of "details"? This book requires no specialized knowledge in the reader and everybody who is interested in flying, including pilots and would-be pilots of all stages of experience, may read it with pleasure as well as profit. (French.) *Rh.*

Le radar, by R. Leprêtre. — Gauthier-Villars, Paris, 1951.

Everybody has heard of radar and its numerous military and civil uses, but many people have no more than a vague idea of the principles, tasks and applications of this new branch of electronics, which was at one time known as "radio-location." There are on the one hand many popular books on this subject, often very superficial, and on the other, scientific works addressed to readers with advanced technical knowledge. M. Leprêtre has therefore set out to describe radar, in simple but accurate terms, to an educated public without previous knowledge of the subject. After defining the various categories of radar, and outlining the theory of electro-magnetic waves (this chapter contains a number of mathematical formulae which can be skipped without damage to the context) and their propagation characteristics, the author describes the different parts of radar equipment, then talks of the uses to which this new branch of engineering was put during the war and its peaceful uses. It is obvious that so comprehensive a book as "*Le radar*" will not be easy reading, but the author must be congratulated on having presented complicated ideas in exceptionally clear terms. His book will surely become a "classic" and a valuable book of reference for those wishing to refresh their memories on one point or another.—The only weak point to our mind is the typographical lay-out which frequently makes reading more difficult. The photographs too would gain greatly if they were reproduced by a different method and on better paper. (French.) *Rh.*

Principles and practice of Radar. 3rd Edition. — By H. E. Penrose and R. S. H. Boulding. — Published by George Newnes Limited, London.

Although written primarily with reference to Marine radar equipment, this very comprehensive manual will prove of the utmost interest to inquisitive readers with an adequate grasp of general radio engineering theory who wish to obtain a thorough knowledge of the operating principles and circuit details of typical modern radar installations. Starting from the basic principles of radio theory, the authors manage to convey a vast amount of information very lucidly and effectively, providing a detailed description of the application of thermionic valves, cathode ray tubes, thyratrons and magnetrons to radar practice, and explaining the functioning of the myriad special UHF and microwave circuits needed to generate and amplify the radar pulses and to detect the resulting echoes, without once having recourse to flights of higher mathematics. There are chapters on display units, position control and indication, and aerial systems; the 3rd edition gives greater prominence to microwave technique, and contains valuable appendices on the theory of transmission lines, wave-guides and cavity resonators and test equipment. This is not a book for the tyro, nor for the acknowledged radar expert; but radio communications engineers, technicians and others who wish to enter the radar field should find it, as the publishers claim, invaluable. From the purely aviation point of view, it is perhaps a pity that no reference is made to the application of radar navigation systems, such as LANAC, GCA and DME in post-war air transportation, nor to wartime systems such as OBOE and GEE. On the other hand, in clarity and layout, the book (which is abundantly illustrated with circuits and diagrams) is comparable to that prewar Radio Officers' classic, the "Admiralty Handbook of Wireless Telegraphy"; it can be no coincidence that one of the authors was formerly on the staff of the Admiralty Signal Establishment. *M. W. M.*

BOOKS RECEIVED :

French Air Ministry Scientific & Technical Publications, distributed by Service de documentation et d'information technique de l'Aéronautique, Paris:

N. T. 34. *Recherches sur l'osmose électrique*, by Luc-Henry Collet.

N. T. 40. *L'hydratation et les phénomènes accompagnant l'hydratation du sulfate de quinine*, by Maurice Prost.

N. T. 41. *Les aspects fondamentaux de la thermocinétique*, by Pierre Vernotte.

N°. 238. *Nouvelles recherches sur la sommation pratique des séries divergentes*, by Pierre Vernotte.

N°. 241. *Etude de la structure des surfaces*, by Georges Blet.

No. 244. *L'allumage électrostatique des moteurs à explosion*, by Marcel Point.

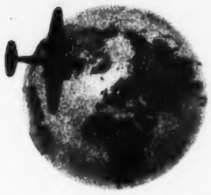
No. 245. *Etude et réalisation d'un équipement électronique pour la mesure et l'enregistrement de faibles variations de capacité ; application aux mesures aérodynamiques et hydrodynamiques*, by Paul Sauvage.

No. 246. *Recherches sur la genèse de la turbulence dans les conduites en charge*, by Raymond Comolet.

No. 247. *Etude des corps plastiques sous pressions élevées*, by Fernand Charron.

B. S. T. 114. *Contribution à l'étude des avions à ailes déformables*, by R. Rouanet.

Das Flugzeug im Wettbewerb mit Eisenbahn und Überseeschiffahrt, by Ernst Hansen, and *Der Flughafen-Zubringerdienst*, by Heinz Piper.— Luftreisedienst Niedersachsen GmbH., Hanover, 1951.



What's in the Air? *

PROVING GROUND FOR WAR

As these lines go to press the fate of the cease-fire negotiations in Korea is still not known. One thing, however, is certain, that all the Powers concerned have used Korea as a vast proving ground for the qualities of men and material and the efficiency of new tactical methods. For example, late in June the USAF put into operation the Lockheed F-94 A all-weather jet fighter, a typical night fighter for high altitudes, for which there can have been but little scope in Korea. Altogether the USAF has used no less than five jet types, namely, in addition to the F-94 A, the North American F-86A "Sabre," the Republic F-84E "Thunderjet," the Lockheed F-80C "Shooting Star" and the North American B-45A "Tornado." The US Navy air units have used the Grumman F9F "Panther" carrier-borne jet fighter and Commonwealth units have tried out the British Gloster "Meteor VIII" jet fighter, which has thus seen its first active service and has just been supplied to No. 77 Squadron, Royal Australian Air Force, in Japan. Air Commodore A. M. Charlesworth, Australian Chief of Staff of the British Commonwealth air forces in Japan, remarked on his return from a tour of inspection that: "We are all waiting to see how British and American jets compare."

*

An interesting contrast is provided by the use of the veteran Douglas C-47 "Dakota" transport at night to drop flares to illuminate targets for the Douglas B-26 "Invader" ground support aircraft—a job that was done by the fighter-bombers themselves at the beginning of the Korea campaign (cf. *Interavia*, Review of World Aviation, No. 11/1950). The Dakota can carry up to 1000 flares, which light up the ground for nearly an hour.

*

USAF personnel trained in Korea are now being posted to training units. Early in June a large number of Korean veterans were sent to Langley Air Force Base (Va), to staff the newly-formed 4400th Combat Crew Training Group.

Lieutenant General Idwal H. Edwards, hitherto Deputy Chief of Staff for Operations, USAF, has been appointed *Commandant of the USAF Air University* at Maxwell (Ala.), in the place of General George C. Kenney, who has retired.

*

Valuable experience has also been collected in the field of psychological warfare. Brigadier General McClure, Chief of the U.S. Army Psychological Warfare Branch, advocated on June 3rd the general introduction of remote-controlled small aircraft (with catapult take-off), carrying loudspeakers and leaflets to persuade enemy troops to surrender. McClure added that a third of the 200,000 Communists taken prisoner in Korea had been made ripe for surrender by psychological warfare methods. According to a United Press report, over 1800 surrounded Communists surrendered to the U.S. Eighth Army near Chunchon on May 30th, after the loudspeaker of a Douglas C-47 had explained to them the hopelessness of their situation.

*

Finally, Korea has given the air transport companies ample opportunity to prepare to take over military transport duties. For example, during the past year PAA has flown 12,971,000 miles on the Korea airlift, carrying roughly 30,000 passengers and 11,000,000 lbs. of freight.

ARMED PEACE

At the moment there is no sign that the Western Powers intend to relax their defence efforts in the expectation of a peaceful end to the Korean conflict.

On June 25th President Truman submitted to the U.S. Congress the third semi-annual report on the Mutual Defence Assistance Programme, from which it emerges that during the period October 5th, 1950, to March 31st, 1951 the USA supplied the European Atlantic Pact countries with a total of 319 aircraft, 9 warships, 3533 tanks and other combat vehicles, 4897 transport vehicles and 1150 guns.

*

The strength of the British Air Forces of Occupation (BAFO) in Germany has been doubled in the last six months and is to be increased still further.

*

In France a new Inspectorate of Airborne Forces came into being on June 1st. It is to concern itself with the development of suitable equipment for the airborne units, the inspection of these units, the establishment of training programmes, etc.

*

Because of the lack of suitable aircraft, Holland has not hitherto been able to organize a tactical air force. Now, however, she is to get 100 Republic F-84E "Thunderjets" for this purpose, the first of which have recently arrived from the USA. Pilots will be recruited from Dutch personnel trained at US air bases.

*

The USA intends to re-equip the Turkish Air Force with jet aircraft as soon as possible. During the next few weeks courses for pilots and mechanics are to start at all Turkish bases; a number of Turkish pilots have already been trained in the USA. The cost of carrying through this programme, which is estimated at $100,000,000, is to be covered from the $8,500,000,000 military aid fund applied for from

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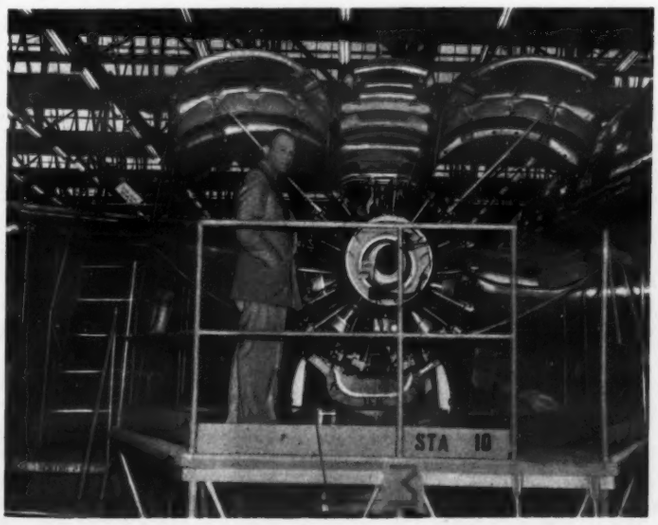
* Extracts from INTERAVIA AIR LETTER, daily international news digest, in English and French. All rights reserved.

During a trip round the world *R. J. Vogels, Public Relations Manager for KLM*, visited Douglas at Santa Monica and Lockheed at Burbank, from whom KLM has ordered seven DC-6Bs and nine "Super-Constellations" respectively.



After being "tenderly cared for" by Russian engineers for a fortnight the two Republic F-84 "Thunderjet" jet fighters which emergency landed at the Czech military airfield of Prague-Kbely on June 8th, 1951, returned to the American zone of occupation in Germany. Unfortunately the wings were not yet "available."

Thomas K. Finletter, US Secretary for Air, visits the Korea front in a Lockheed T-33 (two-seater trainer version of the "Shooting Star").

A four-engined "North Star" of an RCAF unit in Korea being marked with the United Nations badge.

A YEAR'S FIGHTING IN KOREA :

Direct hit by the USAF on a bridge near the 38th Parallel. (Top) : before the attack, (bottom) : the bomb exploding.

Congress in May, of which $415,000,000 is earmarked for Greece, Turkey and Persia.

EASTERN GERMANY PRODUCING MILITARY AIRCRAFT ACCESSORIES

A "Report on Armament Production in the Soviet Zone of Occupation" (based on information supplied by factory staff) recently published by the West German Ministry for Pan-German Affairs contains the following details of production of accessories for aircraft and aerodromes:—

Siemens & Halske's SAG works (Zwönitz, Erz Mountains) is said to be making large numbers of electrical precision instruments for aircraft.

VVB Optik is producing (at the former Carl Zeiss works in Jena) optical sights of the former German type A1, also potentiometers (24 Volt small motors, potentiometer disc 380 mm in diameter, resistance 100 Ohm). An order placed at the end of June 1950 and still not completed is said to have been for 2400 potentiometers.

Large tanks for jet fuel have been made since March 1950 by the SAG Chemische Maschinenfabrik Dudisleben (Kreis Arnstadt). These 10,000 litre tanks are mounted on Studebaker type chassis.

Aerodrome lighting equipment and searchlights are being produced by the Kalorimeter und Kalorifer-Werk (formerly Junkers) at Dessau (lighting equipment approx. 1 m long, searchlight diameter 600 mm).

The following are also being made:—

Winches for barrage balloons, by Transmasch, Unruh & Liebig, Leipzig.

Special accumulators for aircraft by Akkumulatorenfabrik Oberschöneweide;

Jet fuel on nitric acid basis, by Chemische Werke Buna, Schkopau;

Jet fuel on petrol basis, by Benzinwerk Böhlen;

Aircraft petrol (96 octane), by Benzinwerk Böhlen.

INDUSTRY COMRADE PUSH-BUTTON...

Thomas K. Finletter, US Air Force Secretary, speaking at Minneapolis on May 31st, said that America was making rapid strides in the field of guided missiles. That the USA should be speeding up development of long-range weapons is not surprising. The recent atomic bomb experiments at Eniwetok, it is announced by the Atomic Energy Commission, have shown that the blast and heat radiation of exploding atomic bombs have a considerable effect on the structural parts of the releasing aircraft, so that it may well be necessary in the future to drop atomic bombs from guided missiles or remote-controlled aircraft directed to the target from mother aircraft. No wonder that quantity production of apparatus for push-button warfare is now under way at a number of the USA's leading aircraft works and that guided missiles are already in normal service use. The 3499th Mobile Training Group, Chanute Air Force Base, Illinois, which comprises several hundred instructors and officers, enlisted men and civilians, is to instruct USAF personnel all over the world in the maintenance and operation of the new weapons. The Consolidated Vultee Aircraft Corp. has received an order for a large number of guided missiles, which are being made at the Pomona (California) plant (Convair "Terrier" for Naval Aviation).—Douglas has long shown a growing interest in this branch of production and announced early in June the development of an anti-aircraft guided missile, a joint design by Douglas and the Bell Telephone Co. The Fairchild Engine and Airplane Co. is building a 170,000 sq.ft. plant for its guided missiles division; it is to cost $1,750,000 and be ready by the end of 1951.

The appointment of *Lord Ogmore* as *British Minister of Civil Aviation* has disposed of recent rumours that the Ministry of Civil Aviation was to be dissolved and its responsibilities taken over by the Ministry of Transport and the Air Ministry.

THE AIRCRAFT INDUSTRY SETS THE MONEY CIRCULATING.

Two months ago on this page mention was made of work being taken on by leading American automobile and other factories to assist the overworked aircraft industry. This tendency is becoming more and more marked. The proportion of the total output of the aircraft industry provided by sub-contractors can be judged from the figures recently published by the Aircraft Industries Association of America. Half of the dollar volume of orders goes to 60,000 sub-contractors, 87% of them small firms employing 500 persons or less. The engine makers get 28-30% of the volume, producers of electronic equipment, armament and equipment 25% and airframe manufacturers 45%.

It is gratifying to note that some of this prosperity is being reflected in Europe. Hugh Gaitskell, British Chancellor of the Exchequer, told the House of Commons towards the end of May that the United Kingdom had received $2,170,000 from the United States in 1950 in the form of royalties for British jet engines, and would probably receive a considerably greater sum during the current year. And the Washington correspondent of Rome's "Il Tempo" reports that the US Government is considering giving the Italian industry considerable overhaul work on aircraft of the Atlantic powers. In addition the US Department of Defense proposes to place orders for USAF accessories in Italy and to accord Italian firms the appropriate priority for raw materials. In this connection mention should be made of the "International Technical Exhibition" to be held in Turin from September 22nd to October 7th. This is a combination of the former northern Italian "Engineering," "Western Trade Fair" and "Films and Photography" trade shows. President of the Exhibition is Count Giancarlo Camerana, Chairman of the Executive Committee is Giuseppe Soffietti, and Press and Public Relations Chief is Dr. Gino Pestelli (Press and Public Relations Manager for Fiat).

Tendencies in the Hydraulic Controls and Undercarriage Industry

By René Lucien, Ingénieur des Arts et Manufactures, Paris

It was M. René Lucien who, with George Messier, founded the Société Française de Matériel d'Aviation in 1927, the company later becoming known as Messier. After the accidental death of George Messier in 1933 M. Lucien became general manager and technical adviser to the company, of which he is today President and Managing Director. He is a member of the Royal Aeronautical Society, the Institute of the Aeronautical Sciences, the Society of Automotive Engineers and the British Interplanetary Society.—Editors.

Now that the Paris Aircraft Show is over it may be interesting to examine the progress made in recent months in an industry which plays a very great part in aeronautical construction, namely that producing hydraulic control systems and undercarriages.

Why are these two branches grouped together ?

Primarily because undercarriage and hydraulic system constitute an interdependent group in an aircraft.

For example if tyres of a lower pressure are to be used on an aircraft, larger, and therefore heavier, wheels are required, which in turn necessitate an increase in the diameter of the jack to retract the landing gear, which affects the whole of the hydraulic system, the diameter of the piping, the delivery volume of the pumps and the capacity of the tanks.

Thus it will be seen that it is not sufficient to lay down test conditions for individual elements. Each part must be considered with regard to the particular use to which it is to be put, and test programmes must include tests not only of individual characteristics but also of the whole installation, in which each part is examined under conditions as close as possible to those encountered in normal use. This alone will give designers a solid basis for their work and enable them to reduce the risks inherent in first flights to a reasonable minimum.

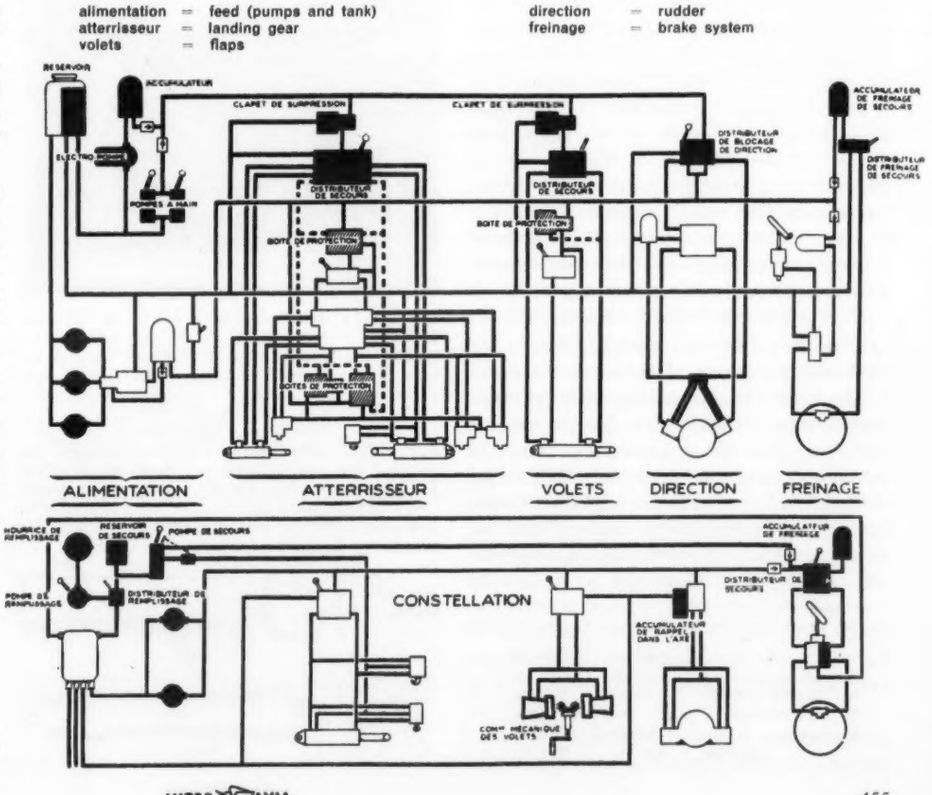
The constantly increasing performance of aircraft and the diminishing space available necessitate constant efforts to produce undercarriages of the maximum simplicity and the minimum weight.

Simplicity and reliability

Simplicity, alas, is one of those factors which does not depend solely on the good will of the equipment manufacturer. There are so many requirements in a modern aircraft that complicated designs frequently become inevitable, particularly where retraction of the undercarriage is concerned. Nevertheless, it must be recognized that designers are coming more and more to understand the importance of the problem and that nowadays they set out from the start to produce an undercarriage structure which is not only an intellectual satisfaction but is also capable of functioning efficiently under all reasonable conditions.

As regards the simplicity of hydraulic systems, much depends on operators' ideas on the subject of safety and on the extent

Fig. 1 : Two different hydraulic systems for the Lockheed "Constellation" : simple emergency circuit for lowering the undercarriage (bottom) and parallel main and emergency system for all circuits (top).



to which they understand that multiplying the devices to obtain a desired result does not always necessarily mean increasing safety.

Logic is a two-edged sword. After every accident it involves the designer in generalizations and thus leads to the appearance of so-called " safety " devices, the very existence of which is frequently a source of danger to the main equipment which was originally perfectly capable of performing its function unaided. This tendency is all the more serious in that the present urgent demand by operators for modern aircraft frequently leads makers to launch quantity production before the prototypes have been adequately proved. They therefore easily fall into the habit of " correcting " a control that has been badly designed or insufficiently perfected by adding a second so-called " safety " device which is no better and which adds to the weight and the complication without increasing safety.

The diagram in fig. 1 compares the circuit used in the " Constellation " to retract the undercarriage, where an auxiliary system is provided solely for lowering the landing gear in an emergency, with that envisaged by a certain airline which requires that the emergency circuit should be capable of replacing the normal circuit at any moment and of functioning under the same conditions as the latter. This would seem to be one of those cases where the " better " compromises the good.

This contention would appear to be proved by the fact that, according to all the reports it has been possible to consult, the reliability of the hydraulic system in the DC-3, an old machine but of robust construction, is considerably greater than that of the more modern system in the " Constellation ".

The necessity for keeping down weight to a minimum is also a very important aspect of the problem. Weight can be reduced by a more judicious design of the parts or the use of high resistance materials or very light alloys, or through a more accurate knowledge of the performance limits required of the various organs, which enables strength specifications to be reduced.

There is a close relationship between the first and the second of these three aspects.

The United States, having nickel-chrome-molybdenum steels which can be welded and can give—after suitable treatment—a resistance of the order of 227,570 psi (160 kg/mm²), can of course produce extremely light structures by using flash or pressure welding. Nevertheless similar results will doubtless be obtainable in future by using light high resistance forged alloys. However, further progress must still be made in the art of forging parts of this kind, so that uniform results can be guaranteed regardless of the direction of application of force in relation to the grain of the metal.

Figs. 2 & 3 : Comparison of main undercarriage legs for the Bréguet « Deux Ponts »; left : cast light metal alloy construction (Messier) for the 761 prototype ; right : the welded steel construction (Messier) of the 763 production version (total height 10 ft. 11 in. = 3.33 m, double wheels 22.4 in. = 570 mm in diameter, with disc brakes).

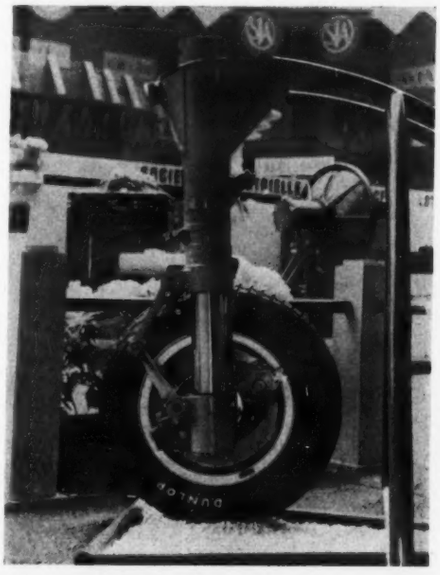


Fig. 4 : The main undercarriage of the Dassault MD 450 " Ouragan " jet fighter (Messier) : welded steel construction 4 ft. 3 in. = 1.3 m. high, wheel diameter 13.4 in. = 340 mm, disc brakes.

Comparative weights for a hydraulic system consisting of the following circuits

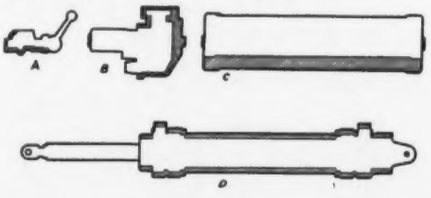
	4,000 psi	2,500 psi
	Total weights in lbs.	
Power circuit	60	80
Undercarriage circuit .	155	187
Bomb door circuit . .	63	78
Flap circuit	100	122
Dive brake circuit . .	58	73
Hydraulic tank, pipes and fluid	245	308
	681	848
Weight saved	167 lb	

Comparative weights of some items in the circuits

	4,000 psi	2,500 psi
	weights in lbs.	
Main U/C jack	46.9	56.2
Flap jack	32.12	54.22
Bomb door jack . . .	13.4	17.27
Dive brake jack . . .	12.63	15.85

On the 2,500 lb. sq. in. system, 6 pumps would be required to achieve the same operating times that 4 pumps give on a 4,000 lb. sq. in. system due to increased jack sizes.

Fig. 5 : Comparison of sizes and weights for certain hydraulic parts at standard pressure (2500 psi = 175 kg/cm²) and at increased operating pressure (4000 psi = 280 kg/cm²). The shading indicates the reduction in size of the equipment at higher pressure



	2500 psi	4000 psi
A — Manual selector	1.0 lbs.	0.85 lbs.
B — Electro selector	4.73 lbs.	4.0 lbs.
C — Accumulator	13 lbs.	7.25 lbs.
D — Jack	17.27 lbs.	13.4 lbs.
diameter	2.8 in.	2.24 in.

Whereas the United States has concentrated almost entirely on the use of forged ferrous metals, France has always been the champion of cast light alloys. It may be noted in particular that while other countries were using aircraft wheels of steel wire or forged or stamped duralumin, France was the first to put aluminium and magnesium alloy wheels on the market.

The practice of making cast undercarriage structures, which had fallen somewhat into disfavour after the introduction of the new American procedures, is now showing a tendency to come into its own again, thanks to the use of new metals, such as the magnesium-zirconium alloys and the magnesium R.E.P.6 alloy specially perfected by Messier for use in the construction of undercarriages.

Alloys of such kinds having the following characteristics for densities similar to that of magnesium :—

breaking load	35,560 psi = 25	kg/mm²
limit of elasticity	21,335 psi = 15	kg/mm²
elongation	4 – 6 %	

enable parts cast of aluminium alloys to be replaced by parts which have the same density as magnesium but which give a 30 % saving in weight.

The future will show to what extent the employment of such metals will open up new prospects for engineers in their constant search for ways of reducing the weight of aircraft.

Choice of hydraulic pressure

The use of higher hydraulic pressures has also been a great factor in weight reduction. The table and fig. 5 show a comparison between a system operating at 2500 psi (175 kg/cm²) — the standard pressure for American systems — and a pressure of 4000 psi (280 kg/cm²) which has been introduced in France and Great Britain by the Messier and British Messier companies respectively.

Considerable research has been undertaken to determine whether there is any advantage to be gained by increasing pressures still further, but it would seem that it is not advisable to go beyond 4270 psi (300 kg/cm²), for the two following reasons :—

1) beyond this pressure it becomes very difficult to make connections which hold sufficiently well, especially allowing for the fact that these connections have to be capable of being assembled by an average workman ;

2) if pressures are increased still further the parts become so small as to require watch-like precision and the whole system would be much too intricate for use under normal operating conditions.

The brakes

Efforts to obtain the maximum possible efficiency of brakes without increasing their weight have led to certain interesting developments. The considerable increase in the amount of energy involved in the landing of aircraft which touch down at speeds in the region of 125 m.p.h. has been the decisive factor here.

Fig. 6 : Disc brake with multiple cylinders, type Messier 22.5. Note the large cooling surfaces.

Everyone knows that where it is a question of dissipating energy by converting it into heat, it is of advantage to increase the temperature to the highest possible degree. It is in fact the difference between cold and hot source that determines, in particular, the rapidity with which the heat produced by the brakes is dispersed into the surrounding air. It has therefore become the practice to use brake discs whose temperature can be raised to 700 to 800 degrees and to expose them as far as possible to the air (fig. 6). At this point the radiation of the red-hot discs combines with convection to obtain the required effect. However, the speed at which a braking operation takes place, an operation which passes a quantity of energy running into millions of foot-pounds within a few seconds into a disc weighing only a few pounds, means that it is not the mean temperature of the disc which is important, but its skin temperature. It is the latter which affects the life of the linings.

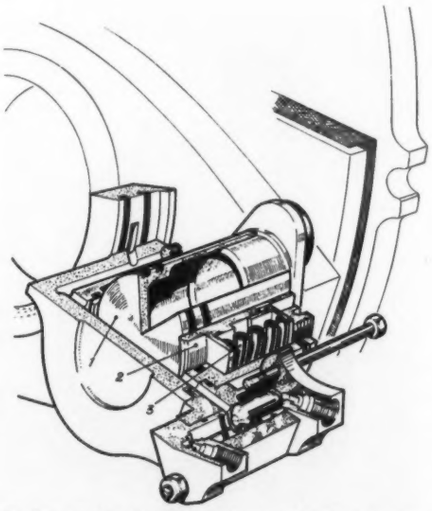


Fig. 7 : Device for rapid release of brake pressure and automatic adjustment of brake disc play.

1 — hydraulic cylinder
2 — jacket
3 — return spring

Brake linings, which are for the most part made of synthetic resin, have a carbonization temperature at which their material disintegrates at a great speed. If thus the skin temperature of the disc is raised too high it causes a rapid deterioration in the linings which may reach the point of complete destruction.

This is the phenomenon responsible for the increase in wear on the linings which becomes noticeable as the speed of aircraft increases, although the amount of energy absorbed remains constant.

It will therefore be understood that it is not a question, in brake systems, solely of absorbing the appropriate amount of energy to bring the aircraft to a standstill but also of allowing for the relative values of mass and speed, the influence of the speed being preponderant on account of the phenomenon referred to above.

One problem that has had to be faced and which results from the necessity, thanks to the high landing speeds, of applying and releasing the brake in rapid succession, is that of the elimination of residual braking effect. This means that the brakes must be provided with powerful return springs to relieve the friction on the discs as soon as the pressure ceases to be felt. In view of the limited space available, springs of this kind are of value only if their travel corresponds to the normal displacement of a single application of the brake. If the springs envisaged had to allow for the total displacement which occurs when the linings are partly worn, their dimensions would be prohibitive.

There is another reason why there must be some device to compensate for wear in the linings and limit the displacement which occurs at the moment the brake is applied : i.e. the quantity of fluid involved.

In order to meet the requirements laid down in various countries the hydraulic fluid tank for the fluid used by the brakes must be large enough to enable a certain number of brake operations, e.g. 25, to be obtained without the action of the pumps. If the amount of fluid required for each application of the brakes increases as the linings become worn, this may mean a considerable increase in the volume of the brake tank, the quantity of fluid used and hence the capacity of the feed tank for the circuit. The whole may represent an increase in weight by 13 to 22 lbs (6 to 10 kg) in an aircraft of 13,200 lbs (6 tonnes).

The advantage of using a compensating device for wear combined with a powerful

spring, to meet these two conditions, is therefore obvious.

The arrangement shown in fig. 7 solves this problem. On the application of pressure, spring (3) is compressed by a constant amount. Its sole function is to release the brakes. As the linings wear, adjustment is made automatically through the displacement under pressure of the central cylinders (1) inside their jackets (2). On release of the brakes play between the free discs and the fixed linings resumes its initial value.

This arrangement represents a considerable improvement and solves a problem which has been greatly preoccupying hydraulic engineers in the USA during recent months, as is testified in the Society of Automotive Engineers' report for December, 1950. This states that one of the problems to which the A-6 committee had been giving its attention was that of taxying resistance due to residual braking effect. Mr. R. C. Rumb, of North American Aviation Inc., it adds, has pointed out that the tank counter-pressure prevents the brakes from being released completely and asks for the immediate specification of a minimum pressure at which the brakes no longer bind.

It goes without saying that the production of such brakes has set problems as to the materials to be used, both for the discs and for the linings. It must not be denied that practically all technical advances in aviation have been based on progress in the materials employed.

Realistic strength specifications

Let us now turn to the saving in weight that can be obtained through more accurate load calculations.

One cannot help being astonished at the lack of curiosity shown by the authorities in a number of countries in this respect. For many years past no attempt has been made to get to the bottom of the problem or to investigate in detail the stresses arising during landing, taxying and take-off.

There have, of course, been examples of outstanding private research, such as that carried out by Lockheed in connection with the construction of the "Constellation" landing gear. There have been some very interesting statistics on certain military aircraft constructed in very large numbers, such as the "Halifax" in Great Britain. However, these results have always been limited to a very small number of formulae and have thus always been so influenced by the individual characteristics of the aircraft that statisticians have tended to draw false general conclusions from these investigations.

Is it necessary to recall that in 1938 the strength specifications for undercarriages were made stricter solely for the Léo 45, which showed a marked tendency to turn aside during take-off, whereas the Bloch 175 undercarriage, with much less stringent specifications, never gave any trouble?

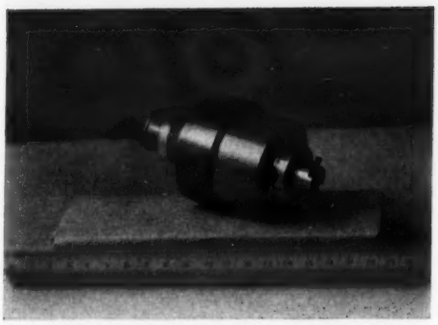


Fig. 8: Messier brake pressure regulator to prevent blocking of the wheels, of extremely small dimensions.

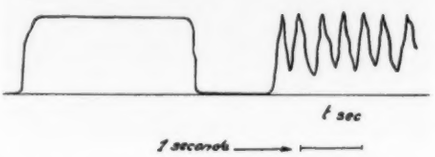


Fig. 9: Comparison between the braking moment of a wheel without brake pressure regulator (left) and with (right).

It is regrettable that no country has undertaken systematic research with a test aircraft in which all the characteristics relating to the undercarriage could be modified at will and which, being used every day in very varied conditions, would enable all the stresses transmitted to the structure to be recorded and hence curves of stresses in various directions and at various points to be constructed.

When it is realized that the difference in weight between a good and a bad undercarriage corresponds to the whole of the payload of an aircraft on a non-stop flight from Paris to New York, it will readily be admitted that sufficient is at stake to warrant some attention to the problem.

It should also be noted that even in the case where strength specifications are reasonable, they always assume extremely low characteristics in the metals employed, particularly when the latter are used in cast parts.

The result is that undercarriages are often built which are found during the static strength tests to be 50% stronger than necessary. This would not matter in the least if the designer—provided, of course, that the cast parts used in construction are properly examined—were permitted to make the production version of the undercarriage correspondingly lighter. It would also be necessary to carry out the strength tests in good time, which is unfortunately not the case. Some day it must be realized that the static strength tests must take place *before* quantity production is started if weight is to be saved.

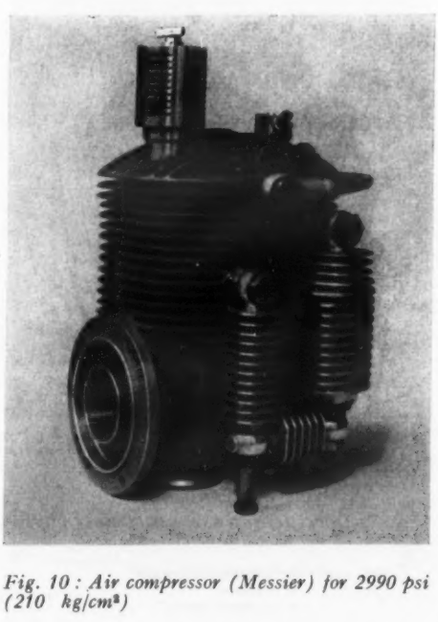


Fig. 10: Air compressor (Messier) for 2990 psi (210 kg/cm²)

Special problems

1. Automatic brakes

As experience has shown, the use of powerful brakes on wheels with high pressure tyres may block the wheels and thus almost instantaneously ruin the tyres.

This occurs not only quite frequently in high-speed aircraft but also from time to time in large aircraft with double wheels. It may happen, in particular in cross wind landings, that the pilot applies the brake when only one wheel has touched the ground and the other is just about to do so. The latter wheel is therefore blocked at the moment it actually touches the ground. The result is serious damage to the tyre, which the pilot cannot avoid because he is unaware of the circumstances causing it.

Aircraft wheels have therefore been provided with automatic brake pressure regulators which completely release the load on the brakes shortly before the wheels cease to turn (cf. figs. 8 and 9).

These devices must, of course, have a very short reaction period, i.e. they must respond in the shortest possible time. To ensure efficient operation 6 to 10 brake releases must be allowed for per second. Today there are several types of brake pressure regulators available. Some are hydraulic, such as the Westinghouse (USA) and Dunlop (Great Britain) devices, and others electro-hydraulic, such as the Hydro-Air (USA) and Messier (France) regulators.

All these solutions are based on the same principle: the rotation of the wheels sets a small flywheel in motion, whose moment of inertia is used directly or indirectly to control the flow of pressure fluid to the brake cylinder.

A similar arrangement was tried out by Piganeau before the war. It worked by centrifugal force. However, it appears

certain that today's equipment is very much better, at any rate, where time of response is concerned.

2. Compressed air systems

During 1950 a new major offensive was made by compressed air systems, which are now gradually regaining the ground previously lost to the hydraulic systems. First in Great Britain, then in France and finally in the USA air compressors for a working pressure of 3000 psi (210 atü) have been produced. These compressors have a variable delivery volume, depending on their purpose. The delivery volume at sea level naturally decreases with increasing altitude, unless pre-compressed air is supplied to the compressor, e.g. air bled off from the compressor of a jet engine. The latter arrangement also has the advantage that one of the compressor stages can be dispensed with, and that relatively high delivery volumes can be obtained with a compressor of small size and weight.

Highly efficient filters and reliable methods of drying the air are, of course, indispensable if the leads are not to become blocked with ice.

So far there has been too little experience of pneumatic high pressure systems to enable any final conclusions to be drawn. It cannot be denied, however, that systems operating with the aid of an expanding fluid entail a great waste of energy. This becomes particularly noticeable when large amounts of energy must be provided for rapid operations.

3. Non-inflammable fluids

A serious objection to hydraulic systems is that the pressure fluid normally used is inflammable and may cause fires. This danger is particularly great when electrical equipment is carelessly placed too near hydraulic circuits. In the USA strict regulations have therefore been introduced regarding the placing of electrical and hydraulic systems in the aircraft, and similar rules are being adopted by more and more other countries. They lay down that electrical instruments must always be installed above the hydraulic installations or better still on one side of the fuselage which is specially reserved for them. However, extensive experiments are being made to develop and introduce into general use a number of fire-proof pressure fluids. They are relatively complicated, since the new fluids must not have a corroding effect on present-day hydraulic packings.

To change over to some other form o packing to suit a possible new fluid would take a long time. The problems are numerous, and it is particularly the problem of packings that does not yet seem to have been satisfactorily solved.

In conclusion it may be stated that the industry engaged on the production of landing gears and hydraulic parts is still developing and endeavouring to render its clients the best possible service.

Unfortunately a marked tendency toward complexity has made itself apparent, nor are the increasing demands made on aircraft designed to reduce this tendency.

The tremendous stresses to which present-day supersonic aircraft—and even certain subsonic aircraft—are exposed in flight necessitate multiple fastenings for all ports and hatches. Pressure cabins also require electro-hydraulic systems which make aircraft more and more complicated and costly.

We may therefore already ask ourselves how long any single country, even the USA, will be able to afford to engage in all branches of aeronautical research. It may well be that here, too, there will be limits which will force sovereign states into the closest possible cooperation.

The International Rotary-Wing Congress

– PARIS, JUNE 26th-29th, 1951 –

By Pierre Lefort, Ingénieur des Arts et Manufactures, Secretary General of the Congress

Paris was the scene of two international aviation events during the second half of June, the 19th International Air Show and, parallel with this, an International Rotary-Wing Congress, organized by the Aero Club of France and the Association Française des Ingénieurs et Techniciens de l'Aéronautique (A.F.I.T.A.= French Association of Aeronautical Engineers and Technicians), with M. Louis Bréguet as Honorary President.

The organizing committee was led by M. Guillaume Busson, President of the Rotary-Wing Committee of the Aero Club of France and M. Jules Jarry, President of the A.F.I.T.A.

Technical experts and practical operators, both French and foreign, flocked to the conference hall where, as the Congress progressed, a vivid and complete picture was drawn of the theory and uses of rotary-wing aircraft.

The object of this article is to give in condensed form the essential points from the lectures and discussions held during the Congress.

THEORY OF THE HELICOPTER

Papers on rotors

Mr. J. Meijer Drees, of the Netherlands National Aeronautical Laboratory, dealt with the problem of automatic transition to vertical descent and vertical landing after an engine breakdown, in a helicopter.

Observations made after an engine breakdown in a Sikorsky S.51 during hovering flight had shown that the pilot must reduce the pitch of the blades immediately after the breakdown. This conclusion is confirmed by the results of theoretical calculations, and underlines the advantage of having a warning signal or a rotor with automatically variable incidence.

Such a machine would have to anticipate critical angles of incidence, avoid dangerous situations during flight near the ground and above all enable the pilot to utilize the rotor energy to reduce his vertical speed immediately before landing.

There are two possible systems :—

1) a device which controls the rotor incidence in a certain definite manner on receipt of the breakdown signal ;

2) a device which regulates the pitch according to the rotation of the rotor, lift, movement of the blades about the vertical axis, accelerations, etc.

The system controlled by the pilot and the automatic system can be connected in series or in parallel.

This lecture was followed by a remarkable film showing the different types of flow of a stream of water round a helicopter model, under different conditions of flight : hovering, vertical, level, oblique, auto-rotation, near the ground.

Mr. Bartram Kelley, Chief Engineer of the Bell Helicopter Division and President of the American Helicopter Society, discussed the stability of two-bladed rotors with the two blades rigidly inter-connected and mounted on the engine shaft by means of a universal joint.

Two types of vibrations appeared during the first tests: firstly *flutter*, which consists of a combined bending and torsional movement by one blade, with displacement of the centre of pressure in relation to the centre of gravity; secondly *weaving*, so called because the level of the blade tips appears to undulate irregularly at a frequency which is noticeably lower than the rotor r.p.m.

Flutter is eliminated by balancing the masses so that the centre of gravity is either on a level with the centre of pressure or slightly ahead of it.

Weaving can be eliminated by overbalancing the masses (by adding weights to the leading edge of each blade at different points along its span) and by shifting the position of the blade's axis of elasticity.

Mr. R. H. Miller, of the Massachusetts Institute of Technology (USA), described the principal factors affecting the stability and manœuvrability of the helicopter; he cited a number of simplifications in the theory of the helicopter in hovering and in forward flight, such as could be applied to the analysis of qualities of manœuvrability and to the conditions required of an automatic pilot. He analyzed the influence on stability about the transverse axis, of variables such as the area of the horizontal tail planes, position of the centre of gravity, displacement of the axis of flapping and forward speed.

M. Kretz, of the Société des Giravions Dorand (France), dealt with the part played by frequency in the dynamics of rotary wings. The role of the basic frequency of the vibratory phenomena encountered in the domain of rotary wings was described and its importance illustrated by a number of examples. A rapid method of analyzing complex dynamic systems such as those encountered in problems of vibration in the controls, the rotor support, the whole helicopter oscillating on the ground, and the tail surfaces, was suggested.

The author then investigated the response of a normal rotor with cyclic pitch control to frequencies varying between zero and infinity, and gave as an example the response in the case of an arbitrary oscillation. The method makes use of operational calculus so as to present the equation of the rotor motion in a convenient form.

M. Normand, of the SNCASE (France), described a device to improve pilotage of a helicopter about the transverse and longitudinal axes.

The qualities that must be demanded of these controls are such that a helicopter must have:

a) a cyclic pitch regulator, composed preferably of a gyroscope fixed to the fuselage by means of shock absorbers (vanes or mechanical shock absorbers);

b) a relay control obeying a differential equation of the first order; the simplest version is a device to apply the appropriate forces to the gyroscope which controls the cyclic pitch.

M. Laufer, of the SNCASO (France) began his talk by enumerating the forces and moments passing through the blade attachments (centrifugal forces, bending moments in the rotational plane, flapping, collective and cyclic pitch variation, drag oscillations), then discussed a system of attaching the blades by means of springs, which offers the advantage of eliminating the necessity for drag dampers.

M. René Dorand, Technical Director of the Société des Giravions Dorand (France) discussed the problem of stabilization in hovering flight.

The relationship between the characteristic of the rotor blades and their mountings (mechanical or fluid shock absorption, type of coupling, flapping and pitch angle, etc.) shows that it is possible to overcome the disturbing effect of the combined roll and yaw, and thus help to make pilotage of the machine easier.

The speaker then described the precautions to be taken to improve stability, showing the influence of the various parameters (spacing of joints, weight per square inch of the blades, braking of the joints, air intake drag, stabilizing suspension, etc.).

Finally he spoke of stabilizers with dephased gyrometer.

MM. Devilliers and de Jessey (Société Bréguet, France) described the principle of the collective pitch control on rotary wings by a controlled regulator.

The speed of rotation of the regulator is connected with that of the rotor, independent of the engine. It is a hydraulic regulator, of special Bréguet design of the "constant-speed" type.

During autorotation at minimum pitch the helicopter can be pulled up rapidly by increasing the pitch, either by hand or by means of the above-mentioned regulator. It is therefore possible to change over rapidly at will from hand operation to regulator or vice versa.

Finally MM. Jean Legrand and Guillaume Busson (France), whose talk was entitled "Systematic investigation of a helicopter model which automatically resumes the autorotation pitch when the engine r.p.m. falls, and which absorbs the tilting moments in horizontal flight without flapping", demonstrated a toy of German design which could probably be developed to relieve the helicopter pilot of some of his constant worries.

The three rotor blades of this model are mounted at a fixed angle and have pivots about which the blades sweep a certain conical sector under the influence of centrifugal force. A return spring and aerodynamic drag act against this process, as in the Sikorsky helicopter. The novelty here is that the forward movement of the blade pushes backwards a lever which twists the blade and increases its angle of attack.

In addition to the elasticity of this torsion bar the aerodynamic forces tend to reduce the angle of attack, since the turning axis of the blade is at the leading edge. When this reduction takes place the lever moves forward.

Tests

M. Decroze (SNCASO, France) described the operating principle of a dynamic test bench for rotor blades.

When the stresses acting on a blade during forward flight are known, the next step is to determine whether such stresses are permissible. As this cannot be done solely by calculations, special tests must be made. The Bréguet company has therefore built a test bench which the SNCASO is now perfecting so that it can fill all requirements with the utmost precision.

M. Mouille (SNCASO, France) dealt with the method of measuring stresses by means of wire resistance strain-gauges, as applied to mechanical tests on helicopters.

By these means measurements can be made of force, displacement, pressure, bending moment, torque and in general of everything that may give rise to stresses of all kinds. Special precautions must be taken in each case to compensate for temperature and reduce secondary effects to the minimum.

Strain gauges are particularly valuable for taking measurements on rotating parts because of their low weight and small bulk. They must, however, be connected to the measuring instruments via a rotating collector, which is difficult to make because of the direct influence of the variations in contact resistance on the measurement.

Thermopropulsion applied to helicopters

There are various types of thermopropulsion which can be applied to helicopters; for example, the ram jet ("Hornet", "Little Henry"), the pulse jet (American Helicopter, Marquardt), compressed air generator inside the fuselage with air ejected at rotor tips, either burned (SNCASO, Ariel) or unburned (Hughes, Dorand, Giravia). A general exposé of the subject was given by M. Garry of the French *Service Technique Aéronautique*, and was followed by papers by a number of other experts, each of whom described the system he himself had adopted.

We shall not here go into *M. Morain*'s system, which has already been described in INTERAVIA Review.[1]

In *M. Dorand*'s (France) system, the motor fluid, slightly compressed and heated by a generator in the fuselage, is passed via a

[1] Cf. *The Adaptation of Gas Turbines to Helicopters*, INTERAVIA' Review of World Aviation, Vol. VI, No. 6, 1951, pp. 331-334.

rotating joint into leads and pipes inside the rotor blades. The pipes, possibly of cyclic aperture, are conveniently situated along the span and the depth of the airfoil. Part of the fluid may be used directly for propulsion and control of the helicopter.

This system can be applied both to heavy load helicopters (helicopter cranes, crop-dusting helicopters) and to transport machines (helicopters or combination aircraft).

In *M. Pouit*'s solution (Société Giravia, France) the motor (gas turbine or reciprocating engine) drives a low-pressure compressor which absorbs the whole of the mechanical power ; part of the air flow supercharges the motor, whose exhaust passes into the leads inside the rotor blades. These leads are heat-insulated by means of the excess cold compressed air which circulates at the same pressure between the leads and the blade structure.

The pre-compression ratio must be selected so as to give the best possible compromise between output, mass power and load losses, when the generator is a gas turbine. There are distinct advantages in the system of separate flows from the point of view of heat insulation and hence from that of output and mass power.

In a second paper M. Pouit dealt with the problem of two-stroke supercharged engines for helicopters and combination aircraft. He concluded by calling upon engine designers to produce engines specially adapted to the needs of rotary-wing aircraft.

The last in the series of papers devoted to thermopropulsion of rotary-wing aircraft was a description by *M. Bruel* (SNCAN, France) of a jet engine used as an auxiliary source of power for the take-off of mechanical helicopters.

In such a system the rotor would be driven by classical methods, the jet devices (rockets, pulse or ram-jets for example) being used only during the relatively short period of take-off and acceleration and then being shut off during normal flight.

The principal advantages of this system are as follows :— low additional fuel consumption, since the time involved is only a few minutes ; increase in noise only on a fraction of the power and for a very short time ; difficulties involved in autorotation with jet nozzles at the blade tips eliminated ; reduction in helicopter's sensitivity to the effects of an engine breakdown.

Different types of rotary wing aircraft

After a historical survey of the different types of rotary-wing aircraft presented by *M. Beaubois*, head of the information service of the I.F.T.A. (Institut Français du Transport Aérien – France), *M. Boris*, director of Hélicop-Air (France) gave a rapid review of the principal mechanical helicopters, then read a note from *Mr. Fr. Piasecki* (USA) outlining ten points in which the helicopter must be perfected before efficient development can be obtained :

1) reliability of operation ; 2) maintenance ; 3) flying qualities ; 4) effects of atmospheric conditions ; 5) vibrations ; 6) payload ; 7) range ; 8) speed ; 9) complexity of design ; 10) cost price.

M. Lepère, director of Société Giravia (France), after presenting the various factors which limit the helicopters' maximum speed (break-away at blade tips, engine resistance moment, Mach number of the moving blade tip), demonstrated that there are three possible forms of combination helicopter, viz. :—

1) fixed wing, with rotor for lift and propulsion
2) fixed wing with autorotating lift rotor and separate propulsion device
3) fixed wing with low-lift rotor rotating under engine power, with separate propulsion device.

Each of these categories may be divided into two, depending on whether the rotor is mechanically or jet powered.

M. Lepère felt that a combination aircraft with the following features should be brought out as soon as possible :—

— jet-driven rotor with gas generator in the fuselage ;
— fixed wing with high wing loading capable of carrying the whole load of the machine above a speed of about 80 m.p.h. (130 km/h) ;
— gas generator consisting of a special two-stroke supercharged injection engine, capable of driving an air compressor for flight as a helicopter or a propeller for flight as a normal aircraft.

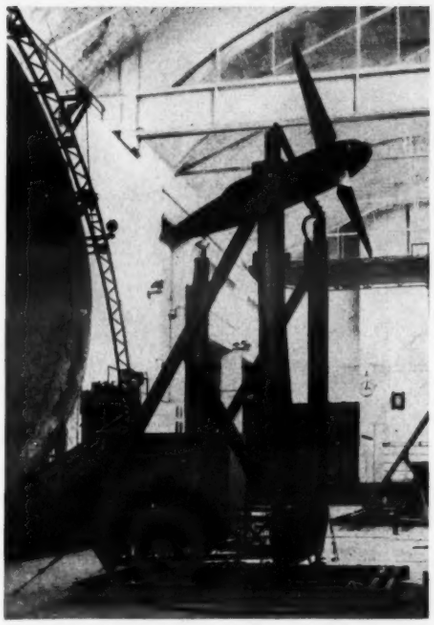


Fig. 1 : Wind tunnel test at ONERA of a helicoplane rotor 13 ft. (4 m) in diameter.

Following along somewhat the same lines *Mr. J.A.J. Bennett* (Great Britain) described the development of the girodyne in the mechanically driven form already produced (Fairey FB-1) and in the form of a machine now being built, with two jet engines (Rotodyne).

Thus both in France and in other countries (the USA also has several girodyne types) the combination aircraft is claiming considerable attention and may well turn out to be the logical conclusion to the development of the helicopter.

Finally *M. G.C. Richard*, research engineer at ONERA (France), described the working principle of the type of rotary-wing aircraft known as the " helicoplane " and its various possible adaptations.

The description of bench tests carried out with a rotor 13ft. (4 m) in diameter (fig. 1) and of other experiments made with it enabled some idea to be got of what this type of rotary-wing aircraft would be like.

The account of the results obtained from several series of tests in the big wind tunnel at Chalais-Meudon indicates that this new system of lift and propulsion promises to be extremely adaptable and versatile.

M. Beauvivier (Timken, France) then spoke of the use of roller-bearings in helicopters, particularly stressing the saving in weight and the improvement in performance which they produce.

Considerable progress had been made in this direction thanks to the use of conical roller bearings specially designed for the purpose. There are two main operating conditions, namely :—

1) constant rotation under radial, or axial, or combined radial-axial loads with capacity to absorb periodic overloads,
2) intermittent rotation or oscillating movement with radial, axial or combined loads.

The conical roller bearing was the ideal bearing for all purposes since its characteristics could always be varied to suit any combination of loads.

(To be continued in our next issue.)

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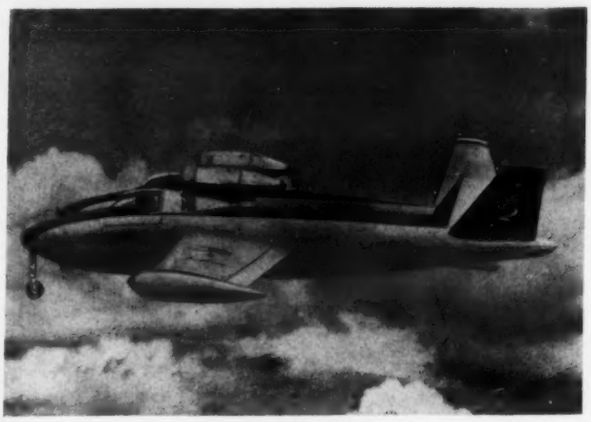

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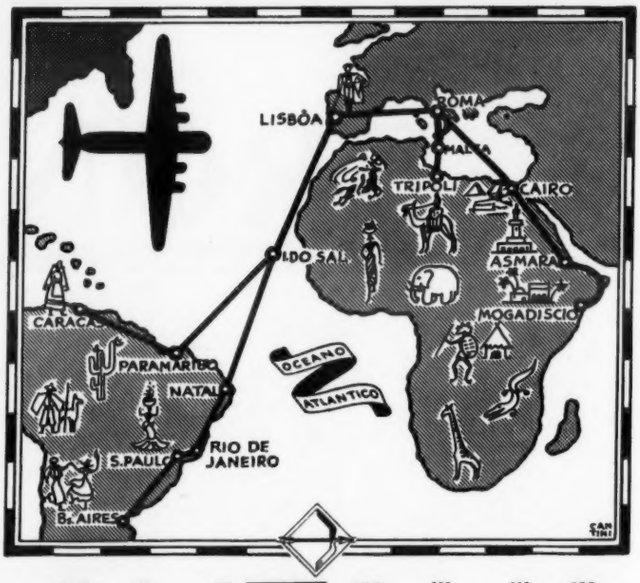

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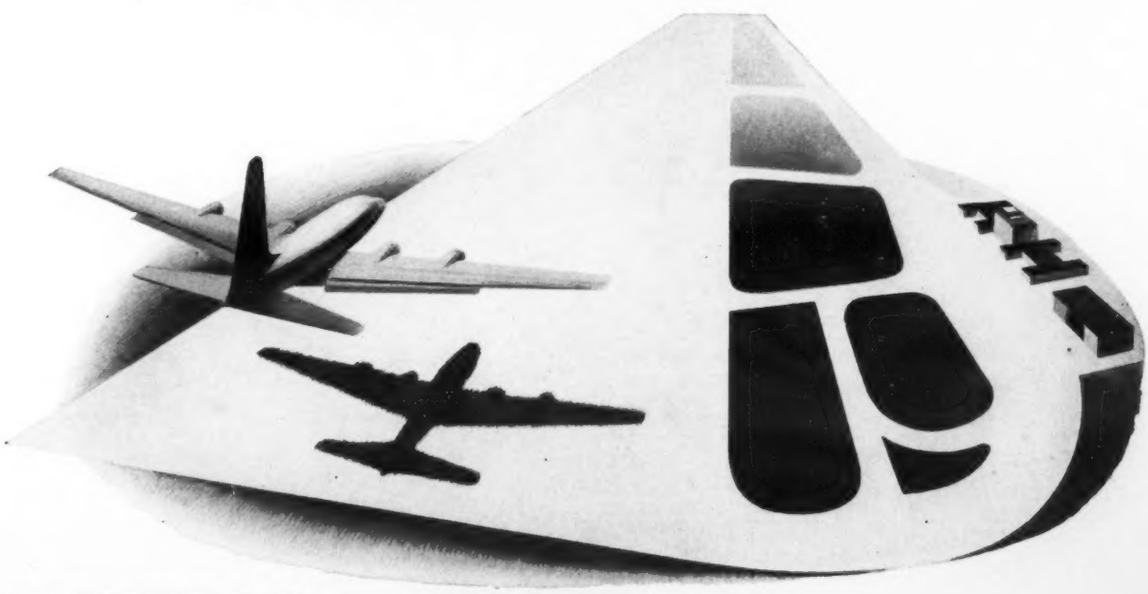

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